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TRACK ELEVATION IN CHICAGO is likely to be considerably extended, owing to a series of recent accidents to pedestrians, carriages and street cars at grade crossings. In the meantime, watchmen have been placed at some of the most dangerous crossings. These accidents are said to be more numerous this year than in any other year since track elevation was commenced. A number of ordinances are now pending, action upon some of which is blocked by the aldermen, who refuse to grant any concessions, although the work is done entirely at the expense of the railways. The following extensions of the track elevation system are covered by these ordinances:

Chicago & Northwestern Ry.: in Kinzie St. west from Ada St. to the present commencement of track elevation; also the Mayfair cut-off line in 46th Ave., from Kinzie St. to Milwaukee Ave.

Chicago, Milwaukee & St. Paul Ry.: from N. 40th Ave. to N. 56th Ave.

Chicago, Rock Island & Pacific Ry.: north from 12th St. into the Van Buren St. terminal station.

Chicago & Western Indiana Ry.: in 46th Ave., from Kinzie St. to Bloomingdale Road; also this road and the Wabash R. R., north of 56th St.

Illinois Central R. R.: south of 67th St.

Lake Shore & Michigan Ry.: north of 12th St. into the Van Buren St. terminal station.

Pittsburg, Cincinnati, St. Louis & Chicago Ry.: in Kinzie St., in connection with the parallel tracks of the Chicago & Northwestern Ry. and the Chicago, Milwaukee & St. Paul Ry.

THE REDUCTION OF GRADES on the Gulf, Colorado & Santa Fe Ry. has now been practically completed, and the southbound grade have been reduced as follows: Fort Worth to Temple, Tex., 127.3 miles, grades reduced from 73.9 ft. to 47.5 ft. per mile; Temple to Belleville, 112.1 miles, 73.9 to 42.2 ft. per mile; Belleville to Sealy, 11.8 miles, 66 to 15.8 ft. per mile. Northbound grades have been slightly reduced in the progress of the work, but this is of comparatively little importance, as the preponderance of the traffic is largely southbound. The annual report of the Atchison, Topeka & Santa Fe Ry. states that incidental to the above work it has been necessary to build 27.58 miles of entirely new line, curvature has been reduced 304°, and the whole line shortened 433 ft.; there were 2,833,670 cu. yds. of earth, 248,885 cu. yds. of loose rock and 413,030 cu. yds. of solid rock removed; 12,705 ft. of wooden and light iron bridges were replaced by permanent work, and 170,000 cu. yds. of ballast and 85,000 new ties were laid. The total cost of the work has been about $1,650,000.——On the Erie R. R., all the short, heavy grades of the Allegheny Division have been reduced to 26 ft. per mile, by cutting down summits and raising sags. This enables eastbound freight trains to take four or five additional cars. In constructing the second track between Galion and Ontario, O., the maximum grades against eastbound trains have been reduced from 60 ft. to 35 ft. per mile, and all the grades between Galion and Meadville are ultimately to be reduced to 35 ft. per mile.

OIL FUEL FOR LOCOMOTIVES continues to give satisfactory results on the Southern California line of the Atchison, Topeka & Santa Fe Ry., according to a statement in the latest annual report of this road. The company has acquired oil lands at Fullerton, where it has several wells in successful operation, and has built a spur 4.24 miles long to reach the oil fields. Other fields have been developed in the vicinity of Bakersfield and Fresno, and all locomotives on the San Francisco & San Joaquin Valley Ry. are being converted into oil burners, while the engines of the Santa Fe Pacific Ry., running between Mojave and The Needles, are also being converted. At the end of the current year, coal will not be used as fuel for locomotives upon any of the company's lines in California.

THE CASCADE TUNNEL of the Great Northern Ry. was completed with a greater degree of accuracy in the engineering work than that noted in our issue of Sept. 27. The grade lines checked to 0.02 ft., or ¼-in., instead of 2¼ ins., as at first reported. The final check on all engineering work was as follows, according to a statement received from Mr. John F. Stevens, Chief Engineer: Error in alinement, 0.02 ft.; error in grade, 0.02 ft.; error in distance, 0.13 ft.

LIGHT-POWERED LOCOMOTIVES may have their capacity increased to meet modern requirements by equipping them with new boilers and cylinders. The Erie R. R. has found the application of high-pressure Wootten boilers and new cylinders to light-weight low-pressure consolidation engines productive of satisfactory economic and practical results. During the year ending with June, 1900, 25 more of these engines were thus remodeled.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred at Bound Brook, N. J., on the Central R. R. of New Jersey, Oct. 12. A through freight, running at high speed, struck the rear end of a local freight which was backing out of a siding. Many cars were wrecked, and the engine-man of the fast freight was killed. The accident is ascribed to a disregard of the block signal by the engineer who was killed.

A BRICK LINED STEEL SMOKESTACK 85 ft. high was recently successfully moved a distance of 450 ft. to a new foundation at the Atha & Illingworth Steel Works, of Newark, N. J. The first stage of the operation was the removal of the foundation and the placing of the chimney upon a big platform or "cradle" of 10-in. timbers. This was a delicate part of the operation, as the cradle had to be built under the stack while the foundation was being torn away. At length, however, the tall tube rested firmly on the cradle, which in turn rested upon a series of rollers and blocks. Four guy ropes were then made fast to chimney and cradle to prevent the high structure from jarring and thereby straining the interior tube of brick. Then the whole was slowly moved over to the new foundation site by means of a horse and windlass such as are employed in ordinary house moving operations. The transfer was accomplished without mishap, and then the new foundation was gradually built under the stack while the cradle was gradually being taken away. The contractor under whose direction the work was done is Frank Camp, of Newark, N. J.

ELECTROLYSIS AT PAWTUCKET, R. I., has been made the subject of a report by Mr. A. A. Knudson, of New York city. Mr. Knudson says an improved system of bonding and track returns might be employed "to so modify the present conditions as to avoid immediate damage," but this would be a temporary expedient. "A double underground or overhead trolley would be an absolute prevention of escaping currents to the water mains." In case the temporary expedient is adopted the maximum difference in potential of rails and water mains should not exceed one volt and a regular inspection should be put in force to see that the limit was not passed. Mr. Knudson suggests the advisability of the passage of a city ordinance, "as has been done in other cities, requiring the railway company to make the changes or alterations" outlined in his report.

AN UNDERGROUND CABLE three miles long was used to transmit an electric current at 30,200 volts in a test recently made by Mr. Henry Floy, Assoc. M. Am. Inst. E. E., for the Gaslight & Power Co., of St. Paul, Minn. The cable is part of a 27-mile transmission line from Apple River, Wis., to St. Paul. It will be operated regularly at 25,000 volts and 5,000 HP. will be furnished for lighting and power purposes.

THE EFFECT OF THE CHICAGO DRAINAGE CANAL on the St. Louis water supply has been under investigation by the officials of St. Louis since the beginning of this year. The annual report of Mr. Edw. Flad, M. Am. Soc. C. E., Water Commissioner of St Louis, which has just been received, contains the following paragraph on the subject:

> For obvious reasons, in view of pending legislation, it is not considered wise to publish at this time the results of the tests or full conclusions based thereon. I deem it proper, however, to state that no data have thus far been obtained which would warrant the belief that we are in serious danger of an epidemic of typhoid fever or other water-borne disease as a result of the opening of the Chicago Drainage Canal.
>
> The tests mentioned were both chemical and bacterial. The samples were collected by the water department until May 1 when all the work in question was "taken up under the direction of the City Counselor under a special appropriation provided for that purpose." The following additional quotation from Mr. Flad's report, in conjunction with what has preceded, suggests the difficulty of drawing definite conclusions from the evidence secured by the investigation, as carried on:
>
> A full report of all the tests made will no doubt be published at some future date, and whether or not such results will suffice to indicate the degree of pollution of our water supply by the sewage from the Chicago Drainage Canal, it is certain that the chemical and bacterial tests will furnish a record of valuable scientific information in regard to these various waters.

THE WAR AGAINST WATER POLLUTION continues in various sections of the country. The city of Oshkosh, Wis., has been ordered by the county court to stop discharging its sewage into Fox River within a year. This decision was rendered on Oct. 5, in a suit brought by Mrs. B. S. Winchell, a riparian owner, for $5,000 damages and an injunction. The plaintiff claimed that the sewage of the city, which is discharged into the river just above her farm, had driven the fish away and rendered the water unfit for her stock; also that the stench from the pollution was a nuisance. The award of damages will be made by a jury.——Another Wisconsin city, Fond du Lac, has received notice of a claim for $7,000 damages, by Mr. Chas. L. Hastings of that city, for the alleged unsanitary condition of the east branch of the river. This, it is said, is the first of a number of claims.——The city of Fitchburg, Mass., is confronted with a suit for pollution of the Nashua River, into which the sewage of the city is discharged. The plaintiff here is the G. W. Wheelwright Paper Co., which has mills on the river, both in Fitchburg and Leominster. The damages claimed are $50,000. The company urges that the sewage still damages it, notwithstanding the fact that it has put in a filtration plant to purify the water of the river. It is reported that the city has decided to employ a sanitary engineer to report on the best means of improved sewage disposal.

SEDIMENTATION BASINS FOR MINNEAPOLIS, a new intake located above the pollution that reaches the two downtown intakes and a large new pumping station, are recommended in a report just made to the city council by Messrs. J. T. Fanning and Wm. de la Barre, Mems. Am. Soc. C. E., of Minneapolis Under this plan, the clarified water would be pumped to the new reservoir, recently built, and a filtration plant might be added whenever found desirable or necessary. The estimated cost of the basins is $430,000. Four new pumps would be needed, in addition to the old pumps that could be moved to the new station.

A VACANCY IN THE NAVAL CIVIL ENGINEER Corps, U. S. N., will occur in January next, and an examination of candidates for the position will probably be held early in December. The position pays a salary of $2,700 per annum at the start. According to the rules last promulgated, candidates for appointment to this corps must be between 25 and 35 years of age, and must be graduates in civil engineering with at least three years' practical experience. A physical examination will precede the professional examination. Applications for permission to take the examination must be made to the Secretary of the Navy. The questions used in the last examination for members of this corps were published in our issue of Jan. 19, 1899.

THE U S. BATTLESHIP "WISCONSIN" averaged 17.25 knots at her official trial on Oct. 11. The run was over a 64-mile course and was made in 3 hrs. 56 mins. 56 secs., the sea being smooth and the weather conditions favorable. The "Wisconsin" was built by the Union Iron Works, of San Francisco, Cal. She measures 368 ft. on the load water line, with a beam of 72 ft. 2½ ins., a displacement of 11,525 tons and 11,000 HP.

AN EXPEDITION TO THE NORTH POLE is to be fitted out by Mr. William Ziegler of New York city, according to a press report. The attempt is to be made under the direction of Mr. Evelyn B. Baldwin, who was a member of the Wellman expedition of 1898-99, and the Peary expedition of 1893-94. It is planned to use two ships, one of which will remain north while the other returns for supplies.

THE DAM AND LOCK IN THE YAMHILL RIVER, Oregon, by which the fall of 13 ft., known as the Yamhill Rapids, is overcome, has been completed and opened to navigation. The lock is built of concrete and is 210 ft. long, 40 ft. wide and 4 ft. deep over the sill. The lower gates are each 25 ft. high and 12½ ft. wide. The lock chamber is filled through wall culverts 3 × 6 ft. in section, which have vertical butterfly valves, and the discharge is through similar valves in the lower gate. The lock masonry, which comprises 8,000 cu. yds. of concrete, is founded on piles. The dam which extends from the river wall of the lock to the opposite shore is 125 ft. long and 30 ft. wide at the base. It is built of timber cribwork filled with stone.

HIGH-SPEED LOCOMOTIVE FOR INTERNATIONAL EXPRESS SERVICE; SCHNEIDER & CO. EXHIBIT, PARIS EXPOSITION.

(With two-page plate.)

The largest and most remarkable display made by any engineering firm at the Paris Exposition is that of the great French corporation of Schneider & Co. On the banks of the Seine, beside the Army and Navy Building, there towers a huge red dome crowned with a two-story turret which bristles with the barrels of rapid-fire guns. This building was erected by the Schneider company chiefly for the exhibit of its ordnance and war material; and while Schneider productions are to be seen in many other departments of the exhibition, the principal effort of the company has been devoted to the display in its own building.

This structure and its contents were so elaborate that it was not until the Exposition had been running for nearly two months that visitors were admitted to the interior of the big red dome.

It was in this building that the huge locomotive illustrated in the accompanying cuts and on our inset sheet in this issue, was exhibited; and because it was shown here instead of with the other transportation exhibits at Vincennes, together with the fact that it did not arrive at the Exposition grounds until the last of June, it was doubtless missed by many visitors to the Exposition.

The representative of Engineering News at the Exposition chanced upon this interesting machine just after its arrival. He had traversed the long aisles in the railway rolling stock exhibit at Vincennes and thought he had familiarized himself with all the curiosities in locomotive construction that the great show had to offer. He had recorded some of his impressions concerning them in an article published in Engineering News of July 5; but that story was across the ocean and in type when this new discovery was made. This will explain why no mention was made of this novel locomotive in that article. Moreover, it fully deserves a separate description because of its originality.

As may be seen from the photograph this locomotive does not at all resemble the usual European locomotive, nor does it attempt to copy American practice. It is true its designer has the same end in view as that which has governed many American locomotive designers, viz., to produce a machine powerful enough to haul heavy express trains at high speed over long runs without stops. He has reached this end, however, by expedients as novel as they are remarkable.

The most striking feature, so far as external appearance is concerned, is the location of the cab clear in front of the boiler. This appears to have been made necessary by the boiler construction. With the very large and high boiler, the engineer would have had no view of the road ahead of him if he had been put back on the footboard with the fireman, according to the common practice in European locomotive construction. The plan in use on American wide firebox locomotives of putting the cab on top of the boiler "amidships" could not be adopted on account of the small clearance limits on foreign railways, so the only thing to do was to place the cab ahead of the boiler, something which has never before been done, so far as we are aware on any locomotive in any country.

Let us not condemn the idea solely because of its novelty, however, without careful examination. Placed in this position, the engineer's vision is wholly unobstructed. The cab is roomy and free from heat, and connections to throttle and valve gear are shorter and more direct than if the cab were on the rear of the boiler. It may be said that the engineer is in a more dangerous position in case of collision, but on roads operated by the block system it may not be amiss to recall "Punch's" classical rule for the prevention of railway accidents—tie a director to the front of the locomotive.

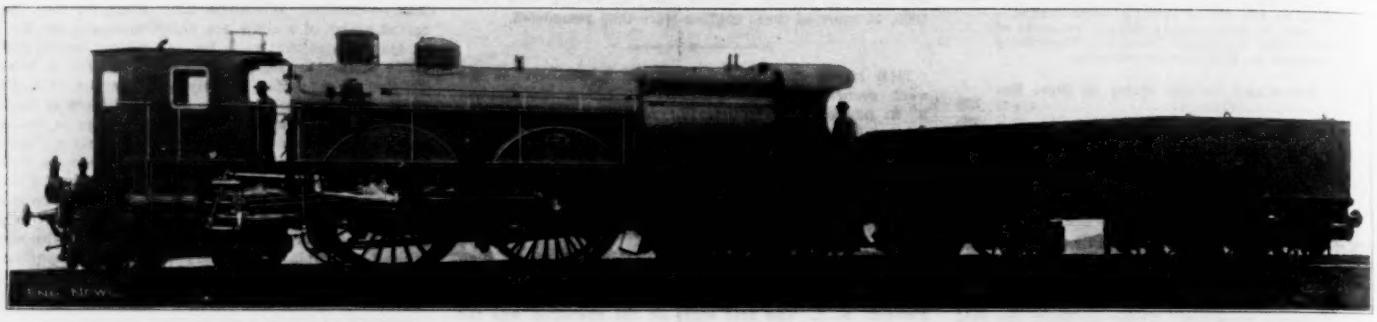
The separation of the engineer and fireman is certainly objectionable; but is after all not so much worse than on some of the recent American locomotives with double cabs. On this French locomotive, however, the fireman apparently has sole control of the water regulation, which has its advantages as well as its disadvantages.

Doubtless the most interesting feature of the machine from a mechanical engineering point of view is the boiler. As seen by the cross-section, the boiler shell is not a circle, but a pear-shaped form. The parallel sides of the boiler shell are held from spreading by three rows of cross-stays inserted between the rows of tubes. The firebox is of the Belpaire type and is notable for its generous width. It is located back of the driving wheels to avoid interference with them, and its weight is carried on truck wheels, as in the American "Atlantic" type locomotive. The American wrinkle of putting the firebox on top of the frame, however, cannot be made to work with the foreign plate frames, so a sort of supplementary frame was devised consisting of bars projecting backward on each side of the firebox and secured to projections from the main frame. In this way a grate nearly 6 ft. wide is secured, so wide, in fact, that two fire-doors are provided. The grate is 8 ft. long, but is steeply inclined, so that it should be a very easy grate to fire; and it will be noted that this arrangement was more readily secured than if the firebox had been placed on top of the frames, as in American practice. The large grate area obtained by the wide firebox, over 50 sq. ft., is a unique feature in foreign locomotive construction.

Instead of a brick arch as a deflector in the firebox, a Ten Brinck water table is used. This device appears to still retain some popularity in Europe, although it was tried and abandoned in America many years ago.

A glance at the cross-section of the boiler on the inset sheet reveals the designer's motive for adopting this peculiar form of boiler shell. He desired to use very large driving wheels to obtain high speed and to provide a very large boiler to maintain it. A circular boiler barrel, made large enough to meet his requirements and placed over the driving wheels, would have brought the center of gravity too high to be safe, and besides that would have exceeded the overhead clearance limits. Even with the adopted design there is scant room for steam dome and stack on top of the boiler shell. The top of the stack is 4.220 meters (13 ft. 10 ins.) above the rail. American clearance limits permit a height of 15 ft. and over.

Referring again to the cross-section, it will be seen that the designer has made his boiler shell as wide as could be squeezed between the frames and has provided room for the number of tubes which he desired by increasing its dimensions from top to bottom to 6 ft. 10 ins. He was able to get in 183 Serve ribbed tubes 2¾ ins. diameter and 14 ft. 3 ins. long. The total tube heating surface is given by the builders as 27[illegible] sq. meters (2,941 sq. ft), but this figure is obtained by counting the entire surface of the ribs of the tubes as heating surface. This, of course, is far from correct. The Serve tubes when kept clean are certainly somewhat more effective than a plain tube, but are far from having an evaporative power in proportion to the total surface exposed to the gases. If the tubes were plain tubes, 2¾ ins. diameter, they would have a total heating surface of 1,730 sq. ft. It is doubtful whether more than 20% in addition should be allowed for the added efficiency due to the Serve ribs, and this would make the total tube heating surface a little over 2,000 sq. ft., which is a very large figure for a European locomotive.



FAST PASSENGER LOCOMOTIVE FOR INTERNATIONAL EXPRESS TRAIN SERVICE.
Built by Schneider & Co., Creusot, France, and Exhibited at the Paris Exposition.

Turning now to the running gear of this locomotive, it may be noted first that this engine, according to its builder's statement, is designed to haul trains weighing 180 to 200 metric tons (200 to 220 net tons) at a speed of 120 kilometers (about 75 miles) per hour, developing 1,800 to 2,000 HP. To attain this speed, the driving wheels are given the unusual diameter of over 8 ft. (98.4 ins.). The truck wheels are 42 ins. diameter. A system of equalizing beams distributes the load to the driving wheels, and the peculiar connection by which the load is transmitted to the bottom of the driving axle-box is noteworthy. The total weight of the locomotive in running order is 80,600 kg. (189,640 lbs.), of which 32,000 kg. (70,400 lbs.) are on the driving wheels. This gives the very moderate wheel load, according to American ideas, of 17,600 lbs. per wheel.

The tender is 35 ft. 5 ins. long over all, and has capacity for so large a load of coal and water (35,000 kg., or 77,162 lbs.), that its rear end is carried on a six-wheel truck. We do not recall any American tender of such a length, and equal capacity could have been given by a shorter and higher body. It is likely that the height was restricted by existing appliances at coal and water stations, making this unusual length necessary to accommodate coal and water enough for very long runs without a stop.

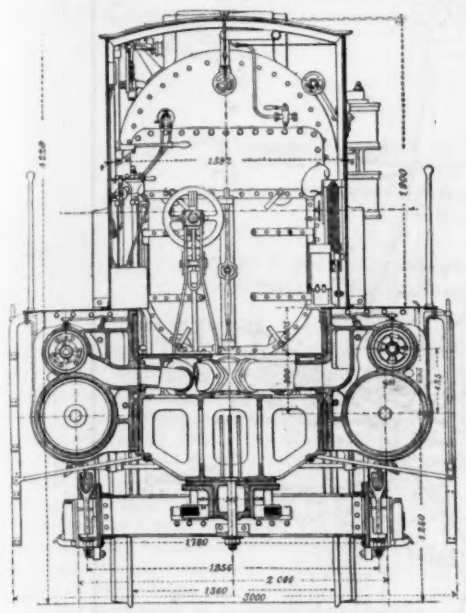
The boiler pressure is high, 213 lbs. per sq. in., but the engine is not a compound. Its two outside cylinders are 20 ins. diameter by 27 ins. stroke, and are located clear in front of the boiler, where a long array of complicated piping is necessary to carry the steam to them and from them.

The front-end arrangements are peculiar, to say the least. There is an extended smoke-box, nearly 6 ft. long, with a cinder-discharging tube in the bottom. The exhaust nozzle is nearly the full size of the exhaust pipe and the draft is equalized by a multiple petticoat pipe arrangement in combination with circular screen spark arresters. The stack projects downward into the smoke-box and is over 2 ft. in diameter at the choke. The whole draft arrangement is very different from American standard practice, yet it is evidently designed with much care and intelligence and

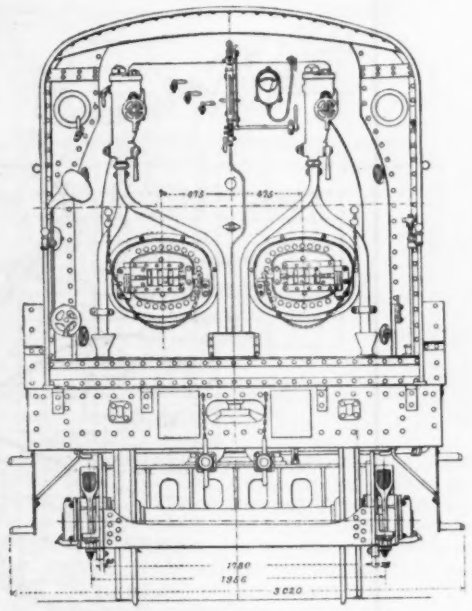
looks as if it should give a strong and well equalized draft with little back pressure.

Nickel steel is used for the firebox plates, stay-bolts, boiler rivets and boiler stays, and also for the cranks and connecting rods. The large driving wheels have cast steel centers. A De Laval steam turbine in the engineer's cab drives a small dynamo, which furnishes electric current for lighting the locomotive and train. Communication between the front and rear cabs is provided for by a speaking tube as well as by bell signals. The principal dimensions of the locomotive are given below in our standard form.

We are indebted to the firm of Schneider & Co., the builders of this locomotive, for the photograph



Cross-Section Through Cylinders.



Rear Elevation.

DETAILS OF SCHNEIDER HIGH-SPEED LOCOMOTIVE.

of the locomotive which is herewith reproduced and for particulars as to dimensions, etc. The drawings we have reproduced from our London contemporary, "Engineering," of September 28.

Running Gear: Driving wheels, diameter	8 ft.	2.4 ins.
Truck wheels, diameter	3 "	5.75 "
Tender wheels, diameter	3 "	5.75 "
Wheelbase: Total engine	40 "	2 "
Tender	25 "	7 "
Engine and tender	73 "	7 "
Weight in Working Order: On driving wheels		70,548 lbs.
On truck wheels		119,092 "
Engine, total		189,640 "
Tender, empty		52,911 "
Loaded		139,073 "
Water in tank		7,417 galls.
Water in boiler		17,400 lbs.
Coal on tender		7 tons
Cylinders:		20 × 27¼ ins.
Connecting rod, length between centers	6 ft.	10.7 ins.
Valve Gear: Type		Walschaert
Boiler: Type		Thuile
Length of smokebox (including extension)		6 ft.
Working steam pressure		213 lbs.
Firebox: Type, Belpaire.		
Length inside	8 ft.	4 ins.
Width inside	6 ft.	2 ins.
Tubes: Serve ribbed, number		183
Diameter outside		2¾ ins.
Length over tube plates	14 ft.	4 ins.
Heating Surface and Grate Area:		
Heating surface, tubes (interior area including ribs)	2,941	sq. ft.
Heating surface, firebox (including water-table)	264	" "
Heating surface, total	3,205	" "
Grate area	50.3	" "
Ratio of total heating surface to grate area		64 to 1
Total adhesive tractive power at ¼ of weight on driving wheels		17,630

THE WATER SUPPLY TUNNELS OF CHICAGO.

I.

The city of Chicago, with its population of about 1,700,000, draws its water supply almost entirely from Lake Michigan, by means of eight tunnels extending under the bed of the lake, and terminating in five intake shafts, located from two to four miles from the shore. The aggregate length of these lake tunnels is 21.97 miles, and in the construction of each one, difficulties of a more or less serious character have been encountered and more or less serious accidents have occurred. Numerous articles on these intake works have been published in our columns, but now that the system is practically complete it will be appropriate to describe the entire system somewhat in detail. A small supply for two of the outlying districts is furnished by artesian wells, as described further on.

GENERAL HISTORY.

Up to 1840, the supply was drawn from wells and the lake, being brought from the lake by water carts. In 1834, a well was dug by order of the Board of Trustees, at the point which is now the intersection of Cass and Michigan streets. In 1836, the State Legislature granted a charter incorporating the Chicago Hydraulic Co., but the works were not commenced until 1840. They were completed in 1842, at a cost of $24,000. The works consisted of an intake pipe, steam pump, reservoir, and wooden distribution pipe. The 18-in. intake pipe extended from a crib in Lake Michigan 700 ft. to a pump well 15 ft. deep, from which the water was forced by a 25-HP. steam pump through about two miles of 2, 3 and 6-in. wooden pipe to a reservoir. The population at that time was about 4,500. In 1851, when the population had increased to 35,000, the city obtained a charter, and the legislature incorporated the Chicago City Hydraulic Co., composed of three commissioners elected by the people of Chicago, and this company purchased the rights of the old private company. Mr. Wm. J. McAlpine, M. Am. Soc. C. E., was the designer of the new works, which were built in 1852-54, and were put in operation during the latter year, the population then being 70,000. The water was led from the lake to a pump well, 20 × 30 ft., 25 ft. deep, and thence pumped to a standpipe 136 ft. high by a vertical beam engine having a steam cylinder 44 × 108 ins., and two single-acting pump cylinders, 34 × 66 ins. There were also about 8¾ miles of iron pipe and a reservoir of 500,000 gallons capacity.

In 1856, the first pipe across the river was laid. In 1854 and 1856, three iron storage tanks on masonry towers were built, the tanks being 60 ft. diameter and 28 ft. high, with the bottom 84 ft. above the level of the lake. These were abandoned in 1879. The intake was at first from the open water of the lake shore, but in 1855 a curved breakwater was built and an inlet basin dredged within it. Before 1860, the water began to give trouble from its foul condition, owing to the discharge into it of filth and refuse from distilleries and packing-houses. Mr. E. S. Chesbrough, M. Am. Soc. C. E., was called in and made an investigation, which resulted in his recommendation of an intake tunnel extending out to clear water. His plans were submitted to and approved by several leading engineers of the day, including Mr. John B. Jervis, M. Am. Soc. C. E.

In 1861, a Board of Public Works was created, and the water-works came under its control, with Mr. Chesbrough as City Engineer. This Board considered his plan, above noted, and recommended it to the City Council, by which it was adopted. The Board was abolished by the City Council in 1876, and the duties were vested in the Mayor, Mr. Munroe H. Heath, but in 1878 another ordinance was passed establishing a Department of Public Works, with a single Commissioner at its head. This arrangement is still maintained. The first Commissioner was Mr. E. S. Chesbrough, who had been City Engineer since 1861, and he was succeeded in 1879 by Mr. Charles S. Waller. In 1881, the Mayor, Mr. Carter H. Harrison, assumed control of this office, and the incumbents since that date are given below. Of these, Mr. Cregier became Mayor in 1889-1890, and Mr. Swift became Mayor in 1895:

1882-'86. DeWitt C. Cregier.	1893. Hiram J. Jones.
1886-.... W. H. Purdy.	1894. John McCarthy.
1887-'88. Geo. B. Swift.	1895. W. D. Kent.
1889-'90. W. H. Purdy.	1896. Joseph Downey.
1891-'92. J. Frank Aldrich.	1897. L. E. McGann.

Mr. E. S. Chesbrough, M. Am. Soc. C. E., was the first City Engineer, and held that office from 1861 to 1878, both inclusive, becoming Commissioner of Public Works for a few months in 1879. His successors were as follows: 1879-1881, De Witt C. Cregier; 1882-1887, S. G. Artingstall, M. Am. Soc. C. E.; 1888-1890, W. R. Northway; 1891, A. W. Cooke; 1892, L. H. Clarke; 1893, Dion Geraldine; 1893-1894, S. G. Artingstall; 1895-1896, L. B Jackson; 1897-1900, John Ericson. Mr. Cregier was Engineer of the Pumping Works from 1864 to 1879, and his reports were those of an experienced engineer. After he became City Engineer he practically consolidated both positions, the men at the pumping stations being merely subordinates in charge of the engines. In 1888-1889, when Mr. Northway was City Engineer, Mr. F. W. Gerecke was made Chief Engineer of the Water-Works system, but this office was afterwards abolished. It is interesting to note that after 15 years' service as Engineer of the Pumping Works, Mr. Cregier was City Engineer for three years (1879-1881), Commissioner of Public Works for four years (1882-1886), and Mayor for two years (1889-1890).

The first intake tunnel was put in service in March, 1867. In 1868, the amount of water pumped averaged 11,500,000 gallons per day, with a maximum of 18,000,000 to 20,000,000 gallons, and Mr. Cregier then stated that in time a new tunnel would be required. In 1871, the Board of Public Works predicted that at the then rate of increase in consumption, the estimated capacity of the tunnel would be reached by the average daily consumption in 1877, or by the maximum consumption in 1875. It was actually reached, however, in 1874. The second tunnel was put in service in February, 1875. In 1884, the Commissioner of Public Works, Mr. Cregier, said that as the city was rapidly approaching the limit of the united capacity of the two tunnels, a new and independent inlet with new and independent pumping works, would soon be absolutely necessary. The capacity of the two tunnels was 150,000,000 gallons, while the pumping engines had a capacity of 130,000,000 gallons, but in 1885 a contract was awarded for another pair of engines, bringing the capacity up to that of the tunnels.

The towns of Hyde Park and Lake built joint water-works in 1874-76, Mr. J. F. Foster being the engineer. The supply was drawn from the lake by a 30-in. cast-iron intake pipe 1,750 ft. long, and was pumped direct to the mains. In 1882, Hyde Park gave up its interest in the plant and built independent works. The new intake comprised a 16-in. cast-iron pipe laid on the bed of the lake for 1,620 ft., and a 5-ft. tunnel, 1,000 ft. long, extending from the pipe to the pumping station. The intake pipe and crib were described in Engineering News, Jan. 12, 1889. The water was pumped direct to the mains. The original works were abandoned in 1889, after the annexation of Lake to Chicago. The town of Lake View built works in 1875-76, the engineers being Mr. J. A. Cole and Mr. John W. Alvord. The system included direct pumping and pumping to two tanks 12 and 15 ft.

in diameter, the bottoms of the tanks being 16 ft. above the level of the lake. There were two intake pipes; one 16 ins. diameter and 1,700 ft. long, the other 20 ins. diameter and 2,000 ft. long, both extending from the pump well to a wrought-iron crib, 16 × 16 ft., and being provided with flexible joints. Previous to 1889, plans were prepared by Mr. S. G. Artingstall, M. Am. Soc. C. E., for a 9-ft. intake tunnel for Lake View. This was to be 6,000 ft. long, terminating at a crib built of concrete and stone masonry in 25 ft. of water. The crib was to be 75 ft. diameter, with a 30-ft. well, supplied by four 4-ft. ports near the bottom, while the top of the crib would be 15 ft. above the water line.

The water-works of Pullman were built by the Pullman Car Co. in 1880-82, Mr. Benezette Williams being the engineer. The supply was taken from the Hyde Park works above referred to, and is now furnished by the 68th St. pumping station of Chicago. The supply is pumped direct to the mains, but in case of fire is pumped to a tank in Pullman, 56 ft. diameter and 31 ft. deep, on a masonry tower 200 ft. high.

In 1889 and 1890, the area of the city of Chicago was increased from 43.5 to 180.5 square miles, by the annexation of Lake View, Lake, Jefferson, Cicero, Hyde Park, Washington Heights, Gano, West Roseland, and Pullman.

In the report of the City Engineer, Mr. Lewis B. Jackson, for 1895, it was stated that there were then over 20 miles of water supply tunnels, through which the city drew its supply from Lake Michigan. The sizes of these tunnels were as follows:

Diam.	Length.	Diam.	Length.
5 ft.	18,590 ft.	8 ft.	9,715 ft.
6 "	39,026 "		
7 "	38,469 "	Total.....	105,800 "

At the present time there are 21.97 miles of lake tunnel, in addition to which there are 15.92 miles of land tunnels leading to the pumping stations. The size, cost and capacity of the several lake intake tunnels are as follows:

Diameter, Length, Cost and Capacity of All Lake Tunnels.

	Diameter, ft.	Length, ft.	Cost.	Capacity, galls.
Lake View	6	9,999	$701,792	45,000,000
Chicago Ave.....	5	10,567	464,866	170,000,000
	7	10,560	415,709	
	7	10,908	299,897	
12th St. or Four Mile	8	9,139	1,104,744	95,000,000
	6	25,200		
Hyde Park or 68th Street..	7	12,353	741,371	105,000,000
	5	8,132		
	6	5,026		
Northeast	10	14,108	610,560	200,000,000
Total (21.97 miles)...		115,992	$4,338,939	615,000,000

The tunnel system is now complete, except that it is proposed to build a tunnel, 10 ft. diameter, from the Carter H. Harrison crib of the northeast tunnel to the Chicago Ave. two-mile crib, connecting with the three tunnels which extend from the latter point. This would be 300 ft. long, and would enable the Chicago Ave. crib to be removed, thus saving the cost of wages and maintenance, and also eliminating the trouble from anchor ice which is experienced at this crib nearly every winter. The accompanying map, Fig. 1, shows the location of the lake and land tunnels, the intake cribs and the pumping stations.

AUXILIARY SUPPLIES.

Besides the main supply from the intake tunnels, certain of the annexed towns now forming a part of the city have independent supplies, as follows:

Rogers Park.—This is at the extreme northeast end of the city limits, and the plant was only acquired from the Rogers Park Water Co. in 1899. The works were built in 1889, C. B. Davis and A. W. Stevens being the engineers, and Geo. C. Morgan the contractor. The supply is drawn from the lake by a 16-in. submerged intake pipe, 1,200 ft. long, leading to the pump well, and is pumped direct to the mains and to the standpipe. There are two Deane pumps, each of 1,250,000 gallons daily capacity, and the water is passed through two filters made by the American Filter Co., each of which is 7 ft. diameter and 7 ft. high. From the filters, the water is pumped to a steel standpipe, 12 ft. diameter and 125 ft. high, mounted on a masonry base 10 ft. high. It was only 100 ft. high until 1891. Its capacity is 84,600 gallons. The plant supplies a population of 5,000 by 19 miles of distribution pipe.

Norwood Park.—This is at the northwest corner of the city limits. The plant was built for the village in 1889 by Geo. C. Morgan, of Chicago. The supply is drawn from an artesian well, the water level in which is 27.5 ft. below the floor of the pumping station. The water is forced to a cistern by compressed air, and a Deane pump forces the water to a steel tank 12 ft. diameter and 36 ft. high, on a brick tower 12 ft. diameter and 66 ft. high. The plant supplies a population of 2,000, by 6½ miles of distribution pipe.

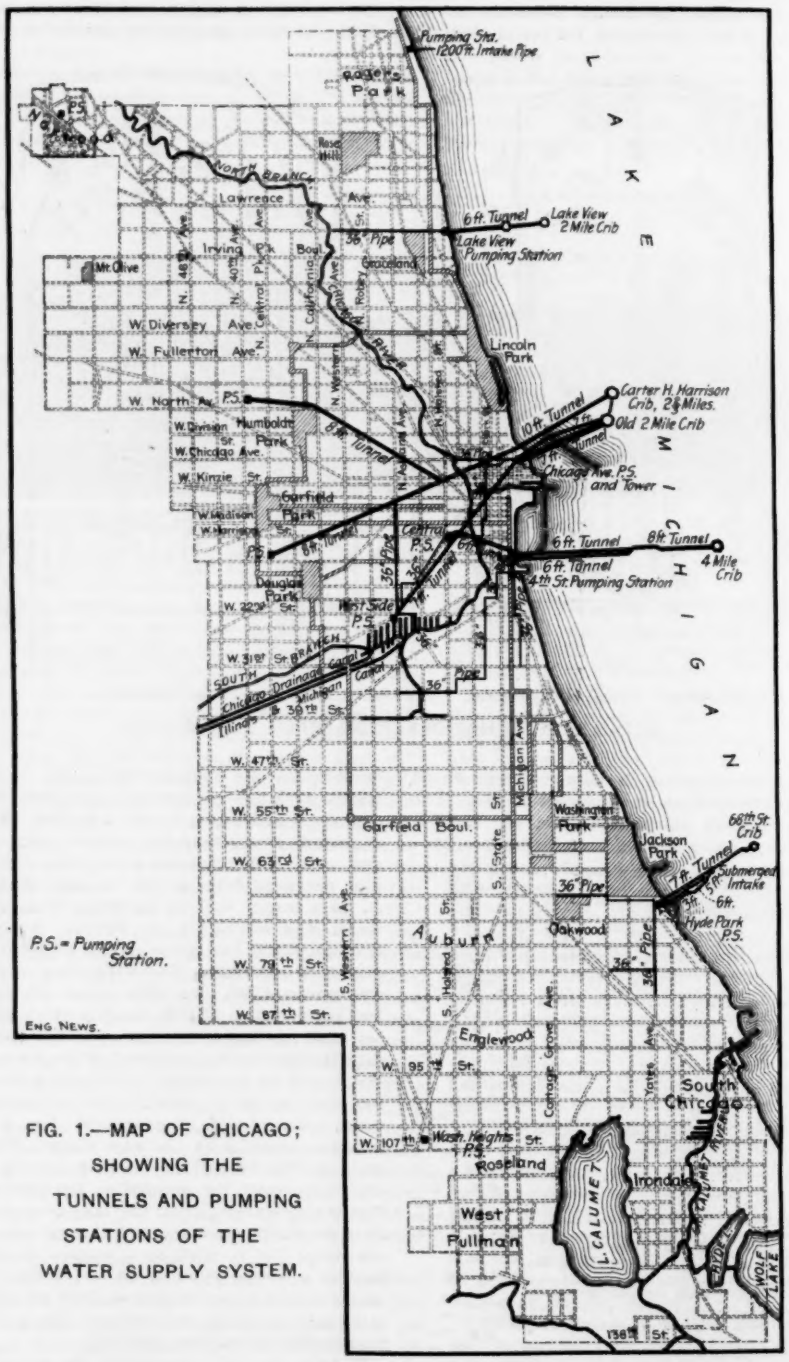


FIG. 1.—MAP OF CHICAGO; SHOWING THE TUNNELS AND PUMPING STATIONS OF THE WATER SUPPLY SYSTEM.

Washington Heights.—This is near the southern boundary of the city. The works were built in 1885 by the village, the supply being drawn from a 6-in. artesian well and pumped by a deep-well pump of 430,000 gallons capacity to a reservoir of 60,000 gallons capacity. From this it was repumped by pumps of 720,000 gallons capacity to a tank. In 1893, the well was enlarged to 10¼ ins. In 1898, two new reservoirs were built, 25 ft. diameter and 166 ft. deep; while the old reservoir was deepened to give it the same depth. This increased the storage capacity to 140,000 gallons. The reservoirs are now filled by a main from the 68th St. pumping station, and the deep-well pump is held in reserve. This plant supplies a population of 6,000, by 13 miles of distribution pipe.

THE CHICAGO AVE. TUNNELS.

First Tunnel.—The first tunnel (No. 1 on Fig. was built from a shore shaft near the end of Chicago Ave., northeast to a crib two miles out the lake. The engineer's estimate was $300,0 which was generally considered as being v much too low, the general impression being t the work would cost more than $1,000,000. T bids, however, ranged from $239,548 to $1,056,000, but the two lowest bids were rejected and the contract was awarded to Dull & Gowen. Work was commenced March 17, 1864, and by March 31, 1865, the tunnel has been pushed 3,023 ft., the progress then being at the rate of 12 ft. per day. The 2-mile intake crib was launched and sunk July 25, 1865. In 1866, progress was frequently made at the rate of 15 ft. per day, and on Aug. 15, 1866, there had been 7,160 ft. of tunnel driven from the shore shaft, and 1,725 ft. from the intake shaft, leaving 1,675 ft. to be driven. The headings met on Nov. 24, 1866, and the tunnel was put in use in the water supply system on March 25, 1867. The

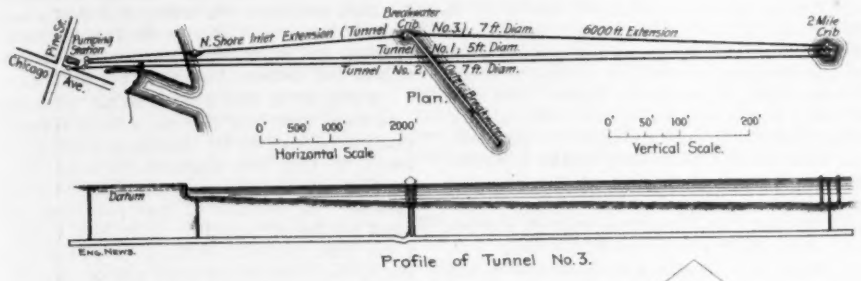
total cost was $457,845. This tunnel was practically circular, but the height was made 5 ft. 2 ins., and the width 5 ft., the top and bottom being circular. This form of section was adopted in order to facilitate the striking or removal of the centering, and has been adopted in all the later tunnels. The same allowance of 2 ins. is made in all cases, regardless of the diameter of the tunnel.

Work was commenced at the shore shaft on March 17, 1864, by the sinking of the cast-iron cylinders for the 9-ft. shaft. The shaft below the cylinders was lined with 12 ins. of brick and had a clear diameter of 8 ft. From the bottom of the shaft a drift was made 50 ft. westward, with a chamber for mounting the transit to give the line of the tunnel. Work on the actual tunnel was commenced May 26, 1864. The tunnel entered the shore shaft by a bell mouth, increasing in diameter from the normal 5 ft. to 6 ft. at the shaft in a distance of 20 ft. This was lined with three rings of brick, but the tunnel was lined with two rings of 4-in. brickwork, and the cavities outside the shell were filled with solid masonry, as it was found impossible to tamp them properly with earth. The upper arch was built on a ribbed center of boiler iron, which diminished the clear space within the tunnel only 4½ ins., and thus allowed the cars to be run to the face of the excavation, which was usually 10 to 20 ft. in advance of the masonry. The iron center was 30 ins. long. About 24 ins. of masonry was laid at a time, and as a rule it was found safe to strike the center within 15 minutes after the arch was keyed.

It was found that the masons could build the upper arch without making the excavation larger than the space required for the brickwork. This was done by driving the last four or five top courses of brick into well-tempered cement mortar first thrown into the cavity. The driving of the bricks effectually filled the spaces which could not have been reached by hand. The toothing of the masonry furnished a guide in driving the bricks. The lower arch was built to templates as in sewer work, and was kept about 6 ft. in advance of the upper arch. The excavation was generally through stiff blue clay, which seldom required bracing if not left for more than 36 hours. Small pockets of sand and quicksand were met with, and occasionally boulders, but very little trouble resulted. A dangerous and unexpected difficulty was the presence of inflammable and explosive gas.

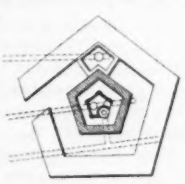
Work was prosecuted night and day by two sets of miners and one set of masons, working eight-hour shifts for six days in the week. About 750 ft. from the shaft, two temporary chambers were made, one in each side of the tunnel, with which they were connected by small short openings, all supported by timbers and planks. A turntable was placed in the tunnel at the connection between the chambers, and this permitted cars to pass each other and enabled trains to be made up. The second set of chambers was made 1,000 ft. further on, and others were made at intervals of 1,000 ft. The passages, however, were lined with brick carefully groined to the tunnel lining, so as to prevent the "creeping" of the clay to any opening left, which caused the brickwork to crack. After the work had progressed 1,000 ft., mules were used instead of men to haul the cars. The ventilation was at first effected by a 6-in. tin pipe carried to the furnace of the hoisting engine above the shaft, but afterwards 8-in. pipes were used and a ventilating fan and engine were installed.

A 4-in. Pike transit was used for the alinement of the tunnel, and was mounted on a tower 166 ft. west of the shaft, and sometimes placed in the back drift or chamber of the tunnel. When the masonry had progressed some distance, a 6-in. tube was sunk from the ground to the tunnel, 280 ft., east of the shaft, through which the line was plumbed. The "trimming" gang, which worked before the masons, consisted of four miners and four men to wheel the cars to and from the nearest chamber. The foreman set lines and "patterns" for the masonry. This shift carried the excavation on 5 ft. and trimmed it to the outside shape of the masonry. The masons gang consisted of three masons, one mortar mixer and four or six helpers. They laid an average of 12 ft. per day, for the whole work, and sometimes 15 ft. per day. The main mining gang, which followed the masons, consisted of four miners and four pushers.



Profile of Tunnel No. 3.

FIG. 2.—PLAN AND PROFILE OF CHICAGO AVE. TUNNELS.



Plan of 2 Mile Crib Enlarged.

It was at first proposed to sink three intermediate working shafts, but these were not built, work being prosecuted only from the shore shaft and intake shaft. The crib for the intake shaft was hexagonal, with 58-ft. sides, and a height of 40 ft. The inner well was of similar shape, the walls of the crib being 25 ft. apart, and the space between them divided into seven compartments. Three of the sides had each an opening or inlet port 4 ft. wide and 5 ft. high. The crib was launched July 24, 1865, and towed to its position, where it was, after some difficulty, sunk by filling the compartments with loose rubble, and then trimming it by pumping in water. A storm disturbed the work, however, and shifted the crib slightly, necessitating a slight deviation in the line of the tunnel. The intake shaft is composed of 9-ft. cylinders, with sliding gates. When the bottom was reached a 50-ft. drift was driven eastward for the alinement of the work and for handling the cars at the foot of the shaft. Tunneling progressed at about 9 1-3 ft. per day, but when the tunnel had reached 2,290 ft. from the intake shaft it was decided to run a timbered drift to the east heading, to be certain how the lines were going to meet. The two headings met Nov. 30, 1866, and it was found that the masonry at the east face was only 7½ ins. out of line with that of the west face. The masonry lining met on Dec. 6.

Between the shore shaft and the pump wells was a gate chamber 16 ft. inside diameter, divided into five compartments by walls having at the bottom rectangular gate openings 3 × 5 ft., 23½ ft. below lake level. The tunnels to the pump wells were 4½ ft. diameter. The tunnel between the shore shaft and the gate chamber was of the same size and form as the main tunnel. As the tunnel was finished before the gate chamber, a temporary connection between the shore shaft and the mouth of the old inlet was made by a timbered drift, 4 × 4 ft., driven from the shore shaft to a 4-ft. brick well 30 ft. deep sunk in the water, the well having two wooden gates just below the surface. When the lake tunnel was completed, the working chambers were filled up and the tunnel was filled with water on March 8, 1867. On March 11 it was pumped out sufficiently to enable the engineer to make an inspection trip in a boat. The formal celebration of the completion of the tunnel and the introduction of pure water from the lake occurred on March 25, 1867. The original estimate was $307,552, and the contract price was $315,139. The extras paid to the contractors brought the amount up to $380,785, and the total cost was $457,845. The increase was in part due to the rise in wages and the disturbance of prices due to the war. The cost per foot of tunnel was $18.45. Some of the prices paid were as follows: Common laborers, $2 per day; masons, $5; engine men, $3; brick, $14 per 1,000; cement, $2 75 per barrel of 300 lbs. The distribution of cost was as follows:

Engineering and superintendence	$28,774
Printing and advertising	375
Miscellaneous	6,250
Labor	2,096
Lumber	1,143
Piles	1,258
Hardware	54
Castings	598
Lake shaft (gates and chambers not in contract)	12,630
Dredging for crib	1,500
Tugs for board and employees	6,718
Discount on bonds	14,685
Opening celebration	979
Paid to contractors, Dull & Gowen	380,785
Total	$457,845

In 1870, plans were made for carrying a 7-ft. tunnel to a new pumping station on the west side as an extension of the lake tunnel. In December, 1880, the old tunnel was pumped out and examined. After 14 years of service there was a deposit 4 to 7 ins. deep on the bottom. The tunnel was thoroughly cleaned out and the transverse chambers above referred to as being used during its construction were bricked up.

Second Tunnel.—The second tunnel was built in 1872-74, and is parallel with and 46 ft. south of the first. Its diameter is 7 ft. At the shore end it is connected with the North Side (or Chicago Ave.) pumping station, and then extends under the city (passing under the Chicago River and the South Branch) to the West Side pumping station at Blue Island Ave. and 22nd St. This new tunnel was suggested in 1869, when the Board of Public Works made a report to the City Council recommending that a new tunnel 7 ft. diameter should be constructed parallel with the old one, connecting with the pumping station, and then continuing westward, passing under the Chicago River to a new pumping station between Halsted St. and Ashland Ave. The site selected was at Ashland Ave. and Blue Island Ave. The increased size was shown to be desirable in view of probable future needs, and the following statement was submitted as to the cost of construction and of pumping with tunnels of different diameter:

Cost of Pumping of Different-Sized Tunnels.

Size of tunnel, ft.	Extra head required for a daily supply 50,000,000 gals; ft.	100,000,000 gals; ft.	Annual cost raising extra height required 50,000,000 gals.	100,000,000 gals.	Extra cost of pumping, capitalized at 7% 50,000,000 gals.	100,000,000 gals.
5	23.17	92.66	$52,345	$422,766	$754,928	$6,039,428
6	9.47	37.88	21,603	172,827	308,618	2,468,942
7	4.44	17.44	10,117	80,938	144,531	1,156,258
8	2.29	9.10	5,224	41,792	74,622	596,028

Estimated Cost of Different-Sized Tunnels.

Size.	Cost.	Size.	Cost.
5-ft. tunnel	$370,983	7-ft. tunnel	$600,356
6-ft. "	448,167	8-ft. "	850,478

The new lake tunnel was located as near the old one as safety would allow because the ground had been proved favorable for the construction of such work. The reasons for connecting with the old pumping station were as follows: (1) To relieve the oldest pumps, which were beginning to be useless at times owing to the loss of head through the old tunnel; (2) the saving in cost of pumping by raising the water in the pump well 8 ft. at first and more afterwards; (3) the great advantage of having two tunnels in case either one should need repairs or cleaning. Bids were invited for the construction of the tunnel, and in 1871 the contract was let to Steele & McMahon, but owing to an injunction work was not commenced until July 12, 1872. It was completed on July 7, 1874, the lines and levels meeting with satisfactory precision.

The character of the ground proved to be very

similar to that encountered in the first tunnel, but there was difficulty in sinking the shore and intake shafts. In the former case the difficulty was owing to trunks of trees near the bottom of the quicksand, 16 ft. below the surface. The intake shaft was of iron 8 ft. 6 ins. diameter.

The intake shaft was sunk in the lake, near the existing intake crib, and a cross tunnel was driven from this shaft to the line of the new tunnel. In sinking this shaft great difficulty was experienced in consequence of water passing from the old tunnel to the new work, and it was found necessary to introduce the pneumatic system. This, however, created a new difficulty, the air escaping up along the outside of the cylinder to the lake. The cylinder was sunk to full depth, however, and the shaft completed, but when tunneling was commenced the water and earth came in so rapidly from above, through the opening made by the escaping air, that work had to be temporarily suspended. By means of a diver the opening was sealed, but then water was found to be coming from the old tunnel, and the diver was unable to stop this leakage from the inside of the latter. It was then decided to pump out the old tunnel, when the leakage was traced to an original defect around the bulkhead placed in the short drift eastward of the shaft. This was easily remedied by closing the drift with solid masonry. The water was turned in again after 17 days, during which time the city supply had been taken from the old inlet basin.

After waiting for the filling on the outside of the new cylinder to become compact, which was aided by draining the water from it through small holes bored in the sides of the cylinder, it was considered to be still too dangerous to attempt to prosecute the work in the ordinary way. The method employed for overcoming this difficulty was described as follows by Mr. Chesbrough in his report for 1874:

> After careful soundings through the small holes bored in the sides of the cylinder, the clay which was known to be very firm originally all round, was found to be very soft for about 3 ft. out on the southeast side, from the bottom of the cylinder to the bottom of the lake, the effect no doubt of the escape of compressed air on that side. It was determined at first to drive pieces of 2-in. bar iron above and around the sides of the drift, through the cylinder and into the hard clay, and then to close the joints between them by another layer of thinner wrought iron. It was afterwards determined to put another floor of wrought iron a few feet above and in a horizontal position. This was composed first of fan-shaped pieces of 2-in. bars with close joints, which were covered above with a layer of ¾-in. bars. After this was done, it was found that the influx of soft mud below the floors had been completely checked.

The total length of the new tunnel is 31,490 ft., including its land extensions, and its top at the West Side pumping station is 21 ft. below city datum or low water lake level. West of the river the grade rises rapidly, to avoid the cost of driving the tunnel through rock and to avoid water known to exist in the rock. The estimated velocity when supplying 100,000,000 gallons per day was 4 ft. per second, which was believed to be as great as could safely be allowed for brick masonry. The contract for the land tunnel was let to Cox Bros., who commenced work in July, 1873, and completed it on Oct. 12, 1874. The cost of the land tunnel was $525,000. The old wooden crib of the first tunnel was replaced by a masonry structure surmounted by a brick lighthouse, and a brick house was built on the upper surface for the keeper. The water was let in in February, 1875.

The original estimate and actual cost were as follows:

	Estimate.	Cost.
Lake tunnel	$400,000	$414,709
Land tunnel	600,356	542,913
Pump. sta., pumps, land, etc.	300,000	497,273
Stone structure at crib	40,000	63,711
Gate shaft	40,000	.....
Enlargement of pipes	119,644	119,644
Total	$1,500,000	$1,638,250

The excess of cost was more than made up in the item of new pumping works, owing to the erection of a larger and finer building and the adoption of better and more powerful engines than originally intended. The engines alone cost $244,612; land, $63,000; leaving $189,660 for foundations, buildings, tunnel and pipe connections, etc.

In December, 1892, the City Engineer, Mr. L. H. Clarke, was instructed to prepare plans for extensions of the two old 5-ft. and 7-ft. tunnels to a new intake, 2½ miles further out. This work was never carried out, but since the completion in 1899 of the new intake (or Carter H. Harrison crib) of the 10 ft. tunnel which parallels these old tunnels, it has been proposed to drive a 10-ft. tunnel between the two intakes, and then to abandon the old two-mile intake. This would cut off the cost of maintenance, repairs and wages at the two-mile crib, and the new Carter H. Harrison crib would then supply the new 10-ft. tunnel, the two old 7-ft. tunnels, and the original 5-ft. tunnel. This is shown by the dotted lines on the plan, Fig. 1.

Third Tunnel.—The third tunnel was built in 1886-87 as an auxiliary to the others, on account of the trouble caused by ice at the intake, while the old shore intake had become useless by decay and by the filling in along the shore. This new tunnel was 7 ft. diameter, and only 1,500 ft. long, extending from the pumping station to a crib constructed to serve as a temporary intake to supply the engines at the north side of the pumping station when the supply from the crib was endangered by ice. The pumping station engines normally drew their supply from the main 7-ft. tunnel. At the new intake, a shaft was sunk and fitted with gates to control the supply, the main supply being still drawn from the old tunnels. In 1891, this tunnel was extended to an intake crib at the northwest end of the government breakwater, a distance of 3,408 ft. The connection with the old work was made on Feb. 1, 1892. After its completion, however, the new intake was practically useless owing to the proximity of the intake to the shore, and its gates were rarely opened. The two old tunnels terminating at the two-mile crib had been taxed to their utmost capacity, and, in order to utilize the new short tunnel and relieve the old ones, it was decided, in 1895 to extend the former 6,000 ft. to the two-mile crib. A contract for this work was entered into on Aug. 22 with Ross & Ross, of Chicago, and work was commenced Sept. 9, 1895. In order to use the shore tunnel as an emergency intake, during the construction of the extension, the specifications provided for the sinking of a new working shaft on the southwest side of the breakwater crib. This provision, however, was changed, and permission was granted the contractors to use the outer shaft in the breakwater crib for a working shaft, and for this purpose to isolate the shore tunnel by closing the intake ports in the inner shaft and by placing a wooden plug over the west eye of the tunnel in the shaft at the Chicago Ave. pumping station, the contractors agreeing to have these shafts opened up for use at the request of the city. Owing to the insufficient port area and the small size of the well at the two-mile crib, it was decided to sink a new intake shaft between the crib proper and its protection breakwater and to protect the same with a pile crib filled with riprap.

The contractors commenced operations at the breakwater crib on Sept. 9. After considerable delay on account of improper machinery, etc., the shaft was finally pumped dry and the eye of the new tunnel was turned on Oct. 21. The work from this shaft up to the end of the year progressed without any serious interruption, only delayed a few days by fire damp and storms. During the year 1895, 1,344 ft. of tunnel were built, the progress by months being as follows:

Month.	No. of working days.	Progress.	Daily average.
October	6	122 ft.	19.3 ft.
November	26	636 "	24.5 "
December	23	586 "	25.48"

Blasting with dynamite in moderate charges of from 5 to 10 lbs. was permitted whenever the ground was of such a nature to allow it with advantage. The character of the ground was mostly blue clay, with strata of loam and pockets of dry gravel. The soil being stratified, frequently needed timber support to hold it up until the brickwork was placed. In many cases for the same reason timbers and boards had to be left permanently in the tunnel and bricked in. The excavated material was by permission dumped on the southeast side of the crib, on condition that it should be removed by dredging whenever this might be deemed necessary.

Work on the new two-mile crib was commenced Sept. 11, 1895, by the driving of piles for the protection of the intake shaft. Work on the crib proper was commenced on Oct. 14, and was practically finished by the end of that month. The cast-iron sections were then placed on the shaft. The length of the cast-iron shaft thus provided allowed of sinking the shaft to about 23 ft. below the bottom of the lake, at which depth it was estimated that the soil would be hard enough to allow brick underpinning, and the balance of the shaft thus built to the required depth. The connection between the two headings was made May 30, 1896, and after the tunnel and shafts had been cleaned out, water was let in July 21, 1896, thus opening the third tunnel for the two-mile intake crib to the Chicago Ave. pumping station.

TWELFTH ST. FOUR-MILE TUNNEL.

In July, 1887, the city authorities approved the plans submitted by Mr. Samuel Artingstall, M. Am. Soc. C.E., then City Engineer, for a tunnel extending four miles under the lake, nearly in a line with 12th St. In October of that year bids were invited for the construction of an 8-ft. tunnel (8 ft. 2 ins. high and 8 ft. wide) to a four-mile intake, the tunnel to be driven from a shore shaft in Lake Front Park, near the foot of Peck Court. The shaft was to be 10 ft. diameter, reaching 80 ft. below datum. The tunnel was to have a rising grade of 1 ft. per mile. The intake was to be submerged, the top of the intake shaft being flush with the bottom of the lake (in 42 ft. of water), and capped with a bell-mouth casting 9 ft. long and 13 ft. in extreme diameter. At least one intermediate working shaft was to be sunk, 2½ miles from shore, and the city reserved the right to stop the tunnel at this point. The working shafts were to be filled up. The two lake shafts were to be sunk from temporary cribs. In order to expedite the work, a working shaft was afterwards sunk ½ mile from shore on the lake side of the U. S. breakwater, as described in our issue of July 5, 1890. A short lateral tunnel was driven northward from the bottom of this shaft, serving as a working chamber from which to drive four 6-ft. headings, two towards the shore and two towards the intake.

For the 2½ mile crib, a caisson, composed of two concentric shells of steel, was built. This was 31 and 70 ft. diameter and 54 ft. high, with a radial brace system in the annular portion. The launching was a failure, however, and the structure was so damaged that it could not be used, and it was eventually broken up. A hollow pentagonal timber structure was finally adopted, and this was sunk in 37 ft. of water by being scuttled.

The idea of a submerged intake was abandoned on account of the difficulty of locating it for repairs, etc., and also on account of the fear of trouble from anchor ice. The design adopted was for a caisson with two circular steel shells, 70 and 120 ft. diameter, with radial bulkheads in the annular portion, which portion was to be filled with concrete. This rested on a polygonal timber cribbing or grillage 15 ft. high, with a bottom 2 ft. thick under the 70-ft. well. Six ports 5 ft. square admit water through this grillage to the well, and are fitted with gates and fish screens. The completed crib was filled with concrete to a depth of 10 ft. (giving it a draft of 27 ft.), and it was then towed out and sunk in 39 ft. of water. The concrete filling was then completed, 11,000 cu. yds. in all being required. The tunnel and its crib were fully described and illustrated in our issues of July 5, 1890, and Sept. 8 and 15, 1892.

The contract was let to Andrew Onderdonk, of New York, in November, 1887, and ground was broken for the 10-ft. shore shaft at Peck Court in December. In January, 1888, quicksand was struck, and caused so much difficulty that eventually this shaft was abandoned, and a new one at the foot of Park Row, 1,200 ft. south, was commenced in May. The 8 ft. tunnel was commenced on June 11, 1888, and was carried through the clay for 278 ft., until quicksand (at the bottom) and swelling clay (at the top) were encountered in July. Work was suspended until September when a hydraulic shield was put in operation, but this was not strong enough, and the entire overlying body of clay, 50 ft. thick, settled down, a deep hole in the lake being thus formed over the

shield, which was abandoned. The contractor then received permission to drive two 6-ft. tunnels instead of the one 8-ft. tunnel. To keep within the hard clay, the grade was lowered about 2,000 ft. from shore, a crib and shaft for the new grade being sunk at the intersection of the line of the tunnel with the government breakwater. The crib was set in March, 1889, and the headings shoreward met the shore headings in August. The lakeward headings were carried on until 1891, when the contractor decided to operate all the headings under air pressures. The lock was placed in the southern heading, and a lateral tunnel was driven to the line of the north heading. Other connecting tunnels or drifts between the two parallel 6 ft. tunnels were driven as the work progressed. In the meantime the difficulties encountered in the work at the 2½ mile shaft, owing to the great quantities of quicksand met with, led the city authorities to abandon this intermediate structure entirely, and to avoid approaching it with the tunnel headings. At about 8,870 ft. west of the intake crib, the two 6-ft. tunnels were therefore united in one 8-ft. tunnel, which was deflected northward so as to clear the intermediate shaft by 350 ft., being then turned south again till the general line of the tunnel was again struck. This was done in order to meet the 8-ft. tunnel being driven landward from the intake shaft, which was begun in January, 1891. The main headings met on June 22, 1892, and the connection between the shore and intake shaft was completed June 27, 1892, but when the air pressure was reduced, a portion of the southern 6-ft. tunnel collapsed, and had to be rebuilt. Water was admitted to the tunnel on Dec. 7, 1892.

The intake crib has a steel caisson, 123 ft. diameter at the bottom and 118 ft. at the top, with a central well 70 ft. diameter, the annular space being divided into 24 compartments by vertical radial bulkheads. It was sunk Oct. 10, 1889.

The new lake tunnel was examined in 1892 by Mr. R. E. McMath and Mr. George H. Benzenberg, Mems. Am. Soc. C. E., under instructions from the city council. They reported that for 1,345 ft. from shore it was in fair condition, though the brickwork was not according to contract. About 6,000 ft. from the entrance the water percolated through and the brick arch had sunk in places as much as 8 ins. A more thorough examination was recommended, and repairs were made at the defective parts.

The lake tunnel, or intake proper, ends at the Park Row shaft. From this point extend the two land tunnels. One of these is a 7-ft. tunnel extending north to the shaft sunk at Peck Court for the starting of the tunnel, and then northwest, crossing the river, until it strikes the old 7-ft. tunnel at Desplaines St., just north of Harrison St. A shaft was sunk at this junction, and from the shaft a 6-ft. tunnel was driven to the new Central pumping station on the south side of Harrison St., near Halsted St. This land tunnel was completed on Jan. 30, 1889. From the shore shaft, an 8-ft. tunnel was to run south to the 14th St. pumping station, but owing to conditions of soil similar to those encountered on the lake tunnel, it was soon found necessary to drive two 6-ft. tunnels instead of the one 8-ft. tunnel. At about 252 ft. north of the pumping station, these two tunnels again unite in a single 8-ft. tunnel, the connection between the 8-ft. single and 6-ft. double tunnels being effected by a succession of varying elliptical cross sections. This land tunnel was completed on March 28, 1889. The 7-ft. land tunnel was built by the contractors for the lake tunnel. The 6-ft. and 8-ft. tunnels were built by the city.

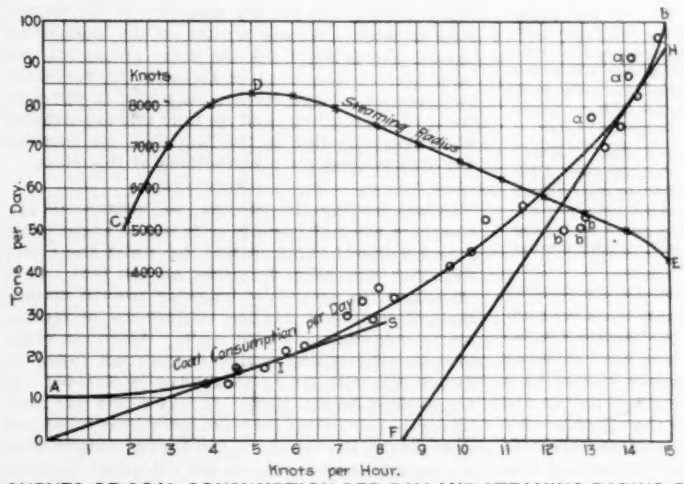
Mr. Bernard Feind, M. Am, Soc. C. E., Assistant City Engineer, was in charge of the lake and land tunnels until his resignation in 1892. He was succeeded by Mr. John Ericson, now City Engineer.

In his report for 1892, the Commissioner of Public Works, Mr. J. F. Aldrich, said that the location of this Twelfth St. four-mile tunnel was most unfortunate, on account of the enormous cost of construction which it involved, and because of the position of the intake in regard to the mouth of the harbor. The completion of the Drainage Canal, however, would, he said, remedy the latter defect. With the completion of the Lake View and Hyde Park Tunnels, and the further extension of the old Chicago Ave. two-mile tunnels, the city "would be able to boast of the finest water supply, both in quantity and quality, of any of the large cities of the world." As that year (1892) was expected to see the completion of the two former tunnels, he recommended that steps should be taken to provide for the extension of the latter. The boast above referred to has not yet been realized.

In order to unite the old system of water tunnels dependent on the Chicago Ave. two-mile crib with the four-mile tunnel from the Twelfth St. crib, in 1896 a 6-ft. tunnel was built on Jefferson St. from a shaft over the old 7-ft. land tunnel at the corner of Van Buren St. to a shaft sunk for the purpose over the Central land tunnel at the corner of Harrison St. This tunnel is about 625 ft. long and can be closed against flow in either direction by a double-faced gate placed in a separate shaft.

THE STEAMING RADIUS AND THE MOST ECONOMICAL SPEED OF STEAM VESSELS.

Two of the vessels purchased by the United States Government for use as auxiliary cruisers during the war with Spain were the "El Rio" and the "El Sud," of the Morgan line, plying between New York and New Orleans, which were renamed, respectively, the "Dixie" and the "Yosemite." The latter vessel was manned by the Michigan Naval Reserves, Prof. M. E. Cooley, M. Am. Soc. M. E., of the University of Michigan, being commissioned Chief Engineer. Prof. Cooley has subsequently published* a very interesting account of this vessel, and of her mechanical equipment and performance, and we are indebted to him for the data presented below.



CURVES OF COAL CONSUMPTION PER DAY AND STEAMING RADIUS OF U. S. S. "YOSEMITE."

For use as a cruiser the "Yosemite" was slightly modified, the principal changes consisting in the rearrangement of the officers' and crew's quarters, the construction of sponsons and port-holes for the batteries, the placing of all wiring and piping below water level, and the placing of 2½ ins. of nickel steel armor about the machinery above water-line. Such new auxiliary machinery was added as was needed for the operation of ammunition hoists, blowers, and a fresh-water distilling plant.

The general dimensions of the ship are as follows:

Length over all	405 ft.
Breadth, moulded	48 ft.
Depth to awning deck beams	33 ft. 5 ins.
Displacement to 20 ft. water line	6,145 tons
Capacity of coal bunkers	1,290.5 tons
Total coal carried (in bags, etc.)	1,481 tons

The main engines are triple-expansion, with cylinders 32, 52 and 84 ins. in diameter by 54 ins. stroke, and unjacketed. At full speed, 14.5 to 15 knots, they run at about 75 revolutions per minute, and develop about 3,700 HP. It was found that between half speed and full speed 5 revolutions per minute corresponded to about 1 knot. The condenser has a total cooling surface of 5,562 sq. ft. There are three double-ended main boilers and one auxiliary boiler, working at 165 lbs. pressure, and having a total heating surface of 10,316 sq. ft. and grate area of 493 sq. ft. The vessel has a single screw.

The maximum engine performance was secured on Sept. 21, 1898, when, with the engines running at 74 revolutions per minute, and developing 3,750 HP., a speed of 14.8 knots was obtained. The economic results were as follows:

*Coal burned per hr., lbs.	8,492
Coal per indicated HP., per hr.	2.26
Grate surface in use, sq. ft.	493.4
Coal per sq. ft. grate surface, per hr.	17.21
I. HP. per sq. ft. grate surface	7.60
Heating surface in use, sq. ft.	1,031.6
I. HP. per sq. ft. heating surface	0.36

From the log the coal consumption at different speeds has been tabulated as follows, the steaming radius being based on a bunker capacity of 1,200 tons:

Knots per hour.	Tons of coal per day.	No. days steaming.	Knots per day.	Steaming radius.
4	14.4	83.3	96	7,997
5	17.4	68.9	120	8,268
6	21.0	57.1	144	8,222
7	25.5	47.1	168	7,913
8	30.8	38.9	192	7,469
9	36.8	32.6	216	7,042
10	43.4	27.7	240	6,648
11	51.0	23.5	264	6,204
12	59.4	20.2	288	5,818
13	69.0	17.4	312	5,420
14	80.0	15.0	336	5,040
15	100.0	12.0	360	4,320

Prof. Cooley says:

The second column shows the daily coal consumption for the speeds shown in the first column. The quantities are taken from a curve plotted from 30 points furnished by the log, and varying from a speed of 3.8 knots to 14.8 knots. The coal consumption with the main engines at rest and with all auxiliaries in use was found to average 10.1 tons per day. Of this amount 5 tons were used for distilling water for the ship's use. The distillers were in use much of the time.

In the accompanying figure A B is the coal consumption curve, starting at zero speed with ten tons, and reaching at a 15-knot speed 100 tons. The group of points, a a a, are from an inferior grade of coal. The group, b b b, are evidently errors of entry in the log.

The tangent OS gives the economical speed at the point of tangency I; for at this point the ratio of coal consumption to speed is a minimum. Therefore, for this ship the most economical speed is 5.5 knots. It must not be inferred, however, that such a speed would be a proper one at which to drive the ship in regular service. The coal consumption is only one of the items entering into the cost of operating a ship. For example, the interest on the cost of the vessel, taxes, insurance, depreciation and repairs, pay and messing of officers and men, oil, waste and other supplies must all be considered. In the merchant service these items would aggregate not far from $250 per day; reduced to a coal basis, coal at $2.00 per ton, this would mean 125 tons. With this quantity a new tangent F H may be drawn, starting from a point on the vertical axis below O, and touching the curve at G. This would give an economical speed of about 14.3 knots per hr., which is the speed at which the ship was operated in the merchant service.

It may be noted that in the ascending part of the steaming radius curve the chief limitation of radius is due to the steam used by the auxiliaries. This is especially important in the case of a warship, and furnishes a strong argument in favor of the replacement of wasteful steam auxiliaries by a more economical system of power distribution by electric motors.

In the case of a passenger vessel the cost of maintaining the service of the ship and the value set by the passengers upon their time, together with considerations relating to advertising, would throw the point G still higher up on the curve. Upon a war vessel, however, the officers and crew must be paid and fed wherever they are, and the most economical speed, except, of course, in time of war, is that at which the least coal is used.

*University of Michigan "Technic" for 1899.

*Pocahontas and New River, mixed.

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page ▼*XI-XXIII. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.*

In our correspondence column this week we publish a seventh letter relating to the "gentle exercise of setting slope stakes." Those who have followed the discussion will recall that it was started by a letter in our issue of July 19. In this letter an engineering professor showed, with the aid of sundry mathematical expressions, that certain algebraic formulas would greatly aid the engineering student in mastering the art of cross-sectioning earthwork. This letter has drawn out a half-dozen others, all from engineers experienced in field-work. The youngest of these, showed in our issue of Sept. 13, how his field experience had led him to use formulas much simpler than the professor's. Two other and older men, one in our issue of Aug. 2, the other on Sept. 20, explained how the working engineer learns to dispense entirely with formulas, mathematics and calculations, except such as he makes mentally as the work proceeds, so that the whole operation of setting slope stakes becomes as simple in the performance as the operation of counting money is to a bank teller. A fifth contributor, in our issue of Sept. 13, described an ingenious rod which he had devised for performing this work with the least possible labor in connection with a special slope tape. Finally, two others tell of an earlier use of these devices. One, in our issue of Sept. 20, stated that the use of both tape and rod has been taught to students at the University of Michigan for some nine years past, while the other, one of the Nestors of the profession, tells us in this issue that the slope tape was used by him on the Vermont Central R. R., as long ago as 1845 and was then well known to engineers engaged in railway construction. Yet this slope tape, notwithstanding its evident merit, appears to be unknown to three of those who have taken part in this discussion.

Why, one is led to ask, did a convenient and labor-saving method of fieldwork once well known to working engineers, fall into disuse and become well-nigh forgotten? It seems to us that the most probable reason is the substitution of the engineering school for the working engineer as the teacher of engineering. We do not say the change was not a good one. It was; and it has been of enormous value in raising the standard of engineering work and of the engineering profession. Yet on the other hand, it is true that in some respects the tuition given by the schools is inferior to that which the old-time student received in the course of his apprenticeship. Too much of the instruction in the schools is given by men whose practical experience has been almost nil. They are bright and able men, in most cases, but they have never been enough in contact with old and experienced engineers to learn the practical methods, the short-cuts, the quick ways of doing work. The methods which they use and teach, they have developed themselves, and while correct in the final outcome, they are too apt to reach these results through devious paths of abstruse mathematics.

We say this not by way of criticism, but to present what we believe to be facts. The engineering schools are doing great and admirable work. Their instruction, on the whole, is vastly better than that given under the old-time "apprenticeship" system. But it is not so good but that it can be bettered, and this matter of practical methods of work is one of the things where the greatest opportunity for improvement exists.

Moreover, this is a field where it is the province of such a journal as Engineering News to supplement the work of the technical school. Valuable labor-saving methods of conducting work, in the field, the shop and the office, are in use in very many places, and yet are unknown to the profession at large. We are always on the lookout for things of this sort; yet the great proportion can only become known to us through the voluntary co-operation of our readers scattered in different parts of the country; and we take this opportunity of calling attention to the fact that our columns are always open for contributions of this class.

Before leaving the subject, we venture to say one more word of friendly criticism of engineering school methods of instruction, for which the above described discussion furnishes an apt text. It is regarding the prevailing tendency toward mathematical treatment and the profuse use of formulas in engineering school work. American engineering schools and engineers have not fallen so deeply into this pit as they have in Europe; yet we are in it deeply enough. It may sound like rank heresy to say it; but we have sometimes wondered whether the time spent on the higher mathematics in our engineering schools did not result in more harm than good to the reasoning powers of the average student. It is not difficult to discern a tendency in the present-day engineering graduate to use his mathematics as a sort of motor-vehicle to carry him through a chain of reasoning with no effort on his own part. We know no better remedy for this sort of disease than the good old and almost forgotten exercise of mental arithmetic. The engineering student should be taught before he sets pencil to paper to solve an engineering problem, to make first a rough and rapid computation mentally, and reach an approximate result, omitting all details and refinements. He can then go over the same ground again with pencil and paper; and his first rough result will serve to check any gross errors in his second.

A chief value of this mental process is the training which it gives to the judgment and the reasoning powers. These rapid mental calculations, often made semi-unconsciously, are frequently the real basis for what are termed "matters of judgment." The engineer who can reason in this way will not fall into the pernicious habit of using formulas and symbols whose exact significance is hazy in his mind.

Another valuable result is that such mentally-performed calculations eradicate the bad habit of using superfluous figures in making calculations. One sees how near the rough mental calculation comes in its result to that reached by the slower process and learns to dispense with useless strings of decimals and unimportant refinements. Finally, as an engineer becomes more experienced, he learns to rely for many calculations almost entirely on his mental work, and knows by experience so nearly what their final outcome should be that any error is at once detected.

There is a man wanted in every engineering office and drafting room and shop and factory in the country. He is the fellow who can be trusted never to make blunders. The engineering student who can fill this specification and the engineering school which is manufacturing material like this sort are on the right track.

STEEL RAIL PRICES AND FREIGHT RATES ON STEEL EXPORTS.

"When Greek meets Greek then comes the tug of war." The position of the steel-makers and the railway companies at the present time reminds one strongly of this old saying. The steel-makers—who are beginning to be anxious to book orders to keep their mills in operation—agreed a few weeks ago to reduce the price of steel rails to $26 (the price having been nominally $35 for some time), and invited the railways to place their orders at the lower figure. The railway companies, however, replied that with steel billets at $16 per ton, $26 for rails looked like a pretty large profit to the steel manufacturer. They were not suffering for rails just at present, and had faith that the price would be lower before it became necessary for them to buy any large quantity. A few orders have been given to the steel mills, it is reported, at the price named, coupled, doubtless, with some stipulations as to reductions in case of further market changes before delivery; but for the most part the railways appear to stand firmly out against the purchase of rails in any considerable quantities at the price fixed by the steel-makers.

On the other hand, the iron and steel interests of the Pittsburg district are at loggerheads with the railways on a proposition in which the relations of buyer and seller are reversed. Iron and steel can now be sold by the makers at a profit for figures approaching those reached in 1896 and '97. This opens the door to a large export business, and here prices are fixed, of course, by the competition of foreign producers. The Pittsburg steel producer, desiring to send his goods abroad, finds that the railways which he must use to reach the seaboard have raised their rates to $3 to $4 per ton, and the great demand for shipping has sent ocean freight rates also skyward.

The situation is a striking illustration of the extent to which competition has been eliminated from the present day commercial world. A half-dozen great companies control substantially all the steel rail production of the United States, and combine to fix the price at which the product shall be sold. The purchaser may pay the price or go without. Similarly, by formal or informal agreement, the railway lines from the Pittsburg district to the seaboard unite in making a uniform rate. If you do not choose to pay the rate, keep your goods at home.

We call attention to the situation, not from any prejudiced or partisan point of view, but as a noteworthy fact. It is idle to deny that competition in these particular cases is dead. Of course, the appeal to "potential competition," as it has been termed, is still possible. The railways have threatened—if newspaper reports are true, as they probably are not—to build their own rail-making plant. So also the Pittsburg manufacturers have threatened to build their own railway to the seaboard, and failing that, have already taken steps to send their products to Europe by the Canadian water route. All these things, however, are in the future. To-day the railway which wants to buy steel rails or the manufacturer who wants to ship them must pay the price fixed or whistle.

Let us hasten to add, however, that sometimes the buyer whistles to preserve the appearance of good humor while he pays what he deems an exorbitant price; and as he whistles he forms the fixed determination to "get square." The ordinary consumer, when he is held up by a trust, is practically helpless; but when great interests like the steel-makers and the railways cross swords, it is indeed a case of Greek meeting Greek.

Nobody objected very seriously last year to

paying the high price which was demanded for rails, for that price was fixed by supply and demand; moreover, the old rails which the railways had to dispose of brought prices which made the net cost of new steel not so very large to the railways after all. This condition, however, is now past, and while the rail mills may book a good many orders at the price they have fixed, it is not at all certain that their profits in the long run will be greater than if they had set a price more nearly in line with the views of buyers.

We have set it down as unlikely that the railway companies have really seriously considered a proposition to establish rail mills of their own. If, however, the steel rail-makers should long persist in demanding what the railways deemed an exorbitant price, such a scheme would be pretty certain to be started. The London & Northwestern railway company has its own rail rolling mill at its Crewe works. The Pennsylvania or the New York Central could easily establish its own steel plant and rail mills. A large part of the necessary raw material would be furnished by its own scrap, and the rail composition could be fixed and the methods of rolling adapted to meet the requirements of service. The Pennsylvania, Long Island, Baltimore & Ohio, and Norfolk & Western, constitute a system with nearly 19,000 miles of track. The annual requirements for rail renewals and extensions on such a mileage would go a long way toward keeping a rail mill busy.

On the other hand, railway managers are not at all likely to take up rail manufacture unless they are in a measure forced to do so. The railway business is quite intricate enough and demands quite enough of railway managers without adding to it manufacturing industries of various sorts. The railways will greatly prefer to pay rail-makers a reasonable profit than to bother with steel manufacture themselves. It is only when the profit becomes an exorbitant one, and is exacted in a way to arouse the discontent and enmity of those who have to pay it that the movement for a railway rail mill is likely to be taken up in earnest.

It should be noted, too, that the railways are not without resources even in the present situation. The amount of rail renewals can be cut down to a very low figure for a year or two if necessity demands. A high price, too, is likely to give an impetus to the rail renewal process, by which worn rails are heated and rerolled and turned out not only as good as new, but, according to the testimony of some experts, in better condition to resist wear than absolutely new rails.

Of even more interest, perhaps, than the schemes of the railways to beat the steel rail combination are the plans, already being carried into effect, of some of the Pittsburg steel producers to beat the railways. The Carnegie Steel Co. has chartered seven ocean steamers of a size small enough to pass through the Welland Canal locks. These will be brought up to Lake Erie and partially loaded with steel products, which will be shipped to that point from Pittsburg over the Pittsburg, Bessemer & Lake Erie R. R., owned by the Carnegie interests. The vessels will then pass through the Welland Canal, Lake Ontario and the St. Lawrence to Montreal, towing probably a barge or two with additional cargo. Here the barge load will be transferred to the steamer, which will then start across the ocean. Besides the Carnegie Co., the American Steel & Wire Co. is reported to have given orders for the building of several steamers to make the through trip from the Lakes to Europe via the Canadian canals; and the grain shipping firm headed by Chas. Counselman of Chicago is reported to have fixed upon a similar policy for handling its products.

It appears probable that at present prices of rail and steamer freights, these ventures may pay good profits. Yet it would be premature to conclude that this transportation route can permanently compete with the rail routes and the steamers from United States ports. We believe we are well within the mark in saying that either the Pennsylvania or the Baltimore & Ohio can move steel from Pittsburg to the wharves in Philadelphia or Baltimore at less cost than it can be carried to Lake Erie by rail and thence by boat to Montreal. Whether or not they will do this business for a less figure than can be made profitable on the competing route, cannot, of course, be said; but it seems unlikely that they will witness such a diversion of profitable traffic and take no steps to retain it.

It may be urged, however, that the ocean passage from Montreal is shorter and cheaper than from Chesapeake or Delaware Bay, and that the steel companies' vessels will have an advantage in this respect over the vessels sailing from the Southern ports. Before accepting this claim it should be more clearly established that the port of Montreal has a net advantage over its United States rivals as a point for transatlantic shipments. Upon the map or globe it certainly has; but against the gain in distance must be set the obstruction by ice during part of the year, and the added risks of navigation in St. Lawrence Bay and on the more northern route across the Atlantic. The former of these is recognized in a substantial increase in the marine insurance rate from Montreal compared with United States ports, and the latter in a restricted lading compared with that permitted to vessels sailing from Baltimore and more southern ports. These disadvantages may more than offset the gain in point of distance in sailing from the St. Lawrence.

Just where the advantage will finally be found to lie, it will take the test of actual competition to determine; and extravagant claims on either side should be taken with a large measure of allowance.

Returning to the matter of the freight rates fixed by the railways on steel products for export, it will hardly escape attention that the new and higher standard of rates has followed close upon the practical concentration of control of the railway outlets to the Atlantic seaboard in two great companies, the Pennsylvania and the New York Central, which are admitted to be working in entire harmony. That large benefits are possible from this unified control is admitted by every candid student of the railway situation. If, however, this practical monopoly of transportation interests is made use of to raise rates above what is necessary to provide good service and return a fair profit on the capital invested, a day of reckoning will certainly come. The diversion of traffic to water routes has already been noted; the building of needless parallel railways is likely to be a further result; and the public demand for stringent legislation and a greater measure of Government control is certainly to be heard.

Perhaps the prices set for steel rails and for the carriage of steel to the seaboard are not too high. Whether they are or are not, we shall not attempt to say. If they are too high, however, the attempt to exact such prices is likely to react upon the corporations responsible for them, and to cause losses which in the long run will overbalance the temporary profits.

LETTERS TO THE EDITOR.

An Early User of the Slope-Tape.

Sir: I used the slope-tape described by Mr. Gillette in your issue of Sept. 13, upon the Vermont Central R. R. in 1845, and it was then a well-known device. Indeed, any fellow would invent it over again after a few days of the gentle exercise of setting slope stakes.

Yours, Ancient.

New York, Sept. 20, 1900.

(We have commented upon this letter in our editorial columns.—Ed.).

Setting Slope Stakes in Cross-Sectioning Earth Work.

Sir: I had hoped that some correspondent would give the complete history of the cross-section rod and tape described by Mr. A. P. Gillette, in his communication appearing in Engineering News of Sept. 13th, 1900. As no one has done this, I venture certain information on the subject, which may be of possible interest. In Engineering News of Sept. 20th, 1900, Mr. C. G. Wrentmore stated that the slope tape and special level rod which Mr. Gillette describes have been used in the classes in surveying at the University of Michigan by Prof. J. B. Davis for the past nine years. For the purpose of placing the credit of this invention where it really belongs, I desire to state that in 1881, precisely such a rod and tape were used on the construction of the Mackinaw extension of the Michigan Central Railroad by Mr. H. F. Bean, who was at the time a resident engineer on this work, and used both the rod and tape in cross-sectioning that portion of the work under his charge. If I remember correctly, Mr. Bean first brought the rod and tape to my attention in the fall of 1880. I think he patented the device and still owns the patent. I believe that Mr. Bean was, without doubt, the original inventor of the rod, though I am not sure as to the tape. My impression is that it had been invented either by him or some one else a few years before Mr. Bean brought it to my attention. In Engineering News of Sept. 20th, 1900, Mr. O. H. Tripp speaks of the tape as "Ward's Tape," but does not state where he derives the name. To my certain knowledge Prof. Davis knew of Mr. Bean's invention as early as 1886. Mr. Bean has made improvements in the rod, doing away with the endless tape and the necessity for reversing it for cut and fill, but the improvements have somewhat complicated it, and some prefer the simpler original form. Much can be said of the practical utility of this rod and tape, permitting cross-sectioning work to be performed with great expedition and without mental labor. Benj. F. La Rue.

The International Correspondence Schools,

Scranton, Pa., Oct. 15th, 1900.

(The above letter was received after the preceding letter, and the editorial notes referring to it on page 264 were in type. Mr. La Rue gives further details as to the original invention of the special rod, described by Mr. Gillette. The tape, however, is, as will be seen from the first letter above, a much older device. We learn from other sources that it has been made and sold by W. & L. E. Gurley for many years.—Ed.).

Further Results With the Mechanical Filtration of Water at East Providence, R. I.

Sir: As you have previously published the report of the five months' initial test of a mechanical filter installed under my direction at East Providence, R. I., by the New York Filter Mfg. Co., in 1899, it may be of interest to you to learn what the efficiency of this filter has been during the last seven months, based upon the results obtained with one sample of water collected and analyzed monthly under the direction of the Secretary of the State Board of Health of Rhode Island.

During the initial test from March 10 to Aug. 2, 1899, the average removal of bacteria during the time when one grain of sulphate of alumina per gallon, containing about 22% of alumina (Al_2O_3), was used, was 99.2%. The number of bacteria in the raw water during this test ranged from 86 to 3,652 per cu. cm. The average removal of color during the initial test in 1899 was 83%.

During five of the seven months, from April to October, 1900, when one grain of sulphate of alumina per gallon was used of the same grade as mentioned above, the average bacterial efficiency has averaged 98.4%, ranging from 97.32% to 99.63%. At no time during this period did the number of bacteria in the raw water exceed 606 per cu. cm. The average number of bacteria in the filtered water was 6, ranging from 1 to 16. The average removal of color during the five months was 91%, ranging from 88 to 94%.

During June and July the sulphate of alumina used was of the same grade as mentioned above, but only ¾ of a grain per gallon was used. The average removal of bacteria for these two months was 92.60%, ranging from 76.41% (when there was only 195 bacteria per cu. cm. in the raw water) to 94.51% (when there was 1,129 in the raw water). The average removal of color for these two months was 78%, ranging from 76 to 81%. The filtered water in every instance was distinctly alkaline. I consider the results mentioned above remarkably satisfactory considering the relatively small number of bacteria per cu. cm. in the raw water.

The results are given in detail in the accompanying table:

Bacteriological Analyses of Samples.

Month.	Bacteria per cu.cm. Raw water.	Filtered water.	Reduction, %	Color, samples.* Raw water.	Filtered water.	Reduction, %	†Sulphate of alumina.
April	600	6	99.00	0.50	0.05	90	1
May	608	16	97.37	0.67	0.06	91	1
August	150	4	97.33	0.58	0.05	91	1
September	364	4	98.90	0.42	0.05	88	1
October	272	1	99.63	0.33	0.02	94	1
June	1,129	62	94.51	0.94	0.23	76	0.75
July	195	36	76.41	0.68	0.13	81	0.75

*Expressed in terms of the platinum-cobalt standard.
†Grains, per gallon.

Very truly yours, Edmund B. Weston.

Providence, R. I., Oct. 12, 1900.

CAST-IRON CAR WHEELS.*

By G. W. Beebe.†

The Interstate Commerce Commission in its report of June 30, 1890, gives the number of cars and locomotives in use in the United States, as follows: Locomotives, 36,234; coaches, 33,595; freight cars, 1,248,826. Taking 8 wheels to each freight car, and allowing 50% of the wheels under coaches and locomotives for the steel-tired and designs other than the cast-iron wheel, there are in use at the present time, 10,269,924 cast-iron wheels. Taking into consideration the small amount of damage done, due to the failure of the cast-iron wheel, it would almost seem that the manufacture of the cast-iron wheel has been brought down to a science. Undoubtedly persistence in the use of the drop and thermal test has been productive in bringing about these favorable results.

A prominent wheel manufacturer made the remark recently that "close inspection and tests had been leading factors in lifting him out of a rut in which he would doubtless have remained had it not been for inspection and tests." A number of manufacturers of cast-iron wheels have made a protest against the thermal test, assuming that in making wheels to meet this test, they would do so at a sacrifice of the wearing qualities. While the adoption of the thermal test does not date back far enough to give correct data on this subject, we think there is no reason for this anxiety on the part of the manufacturer regarding loss in wear in wheels made to stand thermal test specifications, provided the thermal test specified is a reasonable one. For the fact is conceded that, no matter what may be dane with a car wheel, some extraordinary conditions may arise which will break it. The thermal test specifications as required by the C., B. & Q. R. R. are as follows:

The test wheel must be laid flange down in the sand and a channelway 1¼ ins. wide and 4 ins. deep must be molded with green sand around the wheel. The clean tread of the wheel must form one side of the channelway and the clear flange must form the bottom. It will be noted that the width of the channelway is equal to the height of the flange, namely, 1¼ ins. The channelway must be filled to the top with molten cast-iron, which must be poured with two ladles directly into the channelway. The molten iron must be taken from the big ladle directly after a tap for pouring off wheels has been drawn from the cupola. The channelway must be filled with the molten iron in no greater time than one minute after the iron has been taken from the big ladle. No puddling or cooling of the iron will be allowed. If the molten iron boils in the ladles, they must be refilled until all indications of boiling cease before the channelway is filled. The time when the pouring ceases must be noted, and two minutes later an examination must be made, and if the wheel is found cracked in the plates or through the tread, the wheels represented by the test wheel will be rejected. Wheels that are wet or have been exposed to the frost may be warmed sufficiently to dry or remove frost before testing.

In addition to the above, the following recommendation is made:

That at the option of the manufacturer, if the test wheel fails under this thermal test, a second wheel showing the next lower shrinkage size to the wheel which failed and cast on the same date as the failed wheel, may be selected by the inspector and used for test. If the second wheel stands the thermal test all wheels of the same and all lower shrinkage sizes may be accepted, while the wheels of the same and higher shrinkage as the failed wheel must be rejected.

Wheels tested according to the above thermal test specifications, and in conjunction with the Barr drop test, will assure the railways of the greatest degree of safety in using cast-iron wheels. The above recommendations are made for the following reasons, namely: The shrinkage allowed on a cast-iron wheel is ½-in., ¼-in. above and ¼-in. below the mean circumference, divided in 4 tape sizes ⅛-in.; the tape No. 1 or highest shrinkage, are the weaker wheels, conditions being normal. The inspector being aware of this, almost invariably selects the tape No. 1, or highest shrinkage number, for test. He is justified in so doing, for the first thing to consider in the inspection of wheels is the point of safety. If the tape No. 1 fails when in the thermal test, reject them, and allow the inspector to select one of the tape No. 2, or next lower shrinkage number, and if the second wheel fails, reject all of the wheels represented; providing, however, the second wheel stands the thermal test, it seems hardly fair to the manufacturer to condemn the second and lower shrinkage numbers, the inspector being satisfied by test on the second tape sizes that they are sufficiently strong and are hard enough to give the wear. An inspector should make a study of iron, so that he can readily designate at a glance whether the first wheel failing could be attributed to bad iron or some unforeseen abnormal condition in the pitting or handling of the failed wheel.

A wheel can be made of a hard, close grain iron that will stand the drop test or concussion in service, but if subjected to a severe and continued brake application is liable, as a boy says, "to go up in smoke." A gritty, hard chill will not make the mileage that a tough chilled wheel will. A gritty chill will shell out quicker than a tough one, because it will not stand the heat that is caused by severe brake application. Good white iron is tough, as well as being hard enough. There is a great difference in the quality of white iron as there is in gray iron; good white iron has a large proportion of combined carbon; bad white iron has a large proportion of sulphur. I believe the steel-tired wheel proves that the toughness gives the wear. I have not seen or heard of a steel-tired wheel shelling out. I have heard some railway men say that when they can cut the chill of a wheel with a chisel, the wheel will not make good mileage. If this is the case, the steel wheel could not make the mileage that is claimed for it, because you know that the steel-tired wheel is turned before being put into service, and it certainly must be soft in order that it can be turned. The hard, gritty wheels will fail in the thermal test, or by severe brake application.

The manufacturer who will try to pawn off this class of wheels on railroad companies, or the owners of private line cars, providing the inspector does pass them, has become a fossil. He might possibly have been successful in the manufacture of the cast-iron wheel in times gone by, when freight cars were not equipped with air brakes and their carrying capacity did not exceed 15 tons, but certainly will drop out of existence in the advanced stages of railroading.

The following table shows a comparative record of tests made by the writer under the Barr drop, in 1893, as against tests made in 1900; the wheels were all 33 ins. diameter, 585 lbs. weight, and all made by the same maker. The figures give the number of blows required to break them. It will be seen that the tests show a marked improvement in the wheels of to-day compared with those of seven years ago:

Wheels made in.	No. of blows required to break.			
1893	14	21	37	Av'ge 24
1900	175	227	93	" 165

Depth of chill should not exceed ¾-in. in the throat, or $^{15}/_{16}$-in. in the center of the tread. The minimum should not be less than ¼-in. in the throat, or ⅝-in. in the center of the tread. With the maximum depth of chill, $^{15}/_{16}$-in. we get the blending of the white iron through the entire tread and begin to crowd the danger line, and gain nothing thereby. A highly chilled wheel will shell out and become comby by sliding more readily than a medium chilled wheel. In breaking up 300 defective wheels that were removed on account of shelled spots, 95% showed a high chill. The responsibility of the wheel manufacturer is frequently a disputed question. Both parties agree, in the majority of cases, excepting as to the difference in comby and worn flanged wheels. There should be no disputed question as to the comby wheel, as it is a very easy matter to determine whether this defect was caused by a severe brake application or faulty metal.

The matter of fitting wheels, especially at contract shops, does not receive the careful attention in many cases that it should, and many instances can be given showing gross carelessness in pressing the wheels on the axles, and also in imperfect boring and mating of wheels. While visiting a contract shop recently, I noticed them mounting wheels at as high a pressure as 85 and 90 tons. Pressing wheels on axles at as high a pressure as 85 tons will produce strains in the wheel that are very likely to develop and cause trouble after the wheel is placed in service.

It seems to the writer that some of the following recommendations, followed up closely, would lead to better results in the use of the cast-iron wheel:

(1) More attention should be given to the taping and mating of wheels in nearly all contract shops, and in some railway shops the tape sizes that are applied to the wheels where they are manufactured are used without any check. All wheels should be re-taped where they are mounted.

(2) All axles should be centered and gaged. If we press one wheel a little too far on the axle and its mate not quite far enough, we mismate them, also by forcing one wheel to run on the high part of the tread close to the flange, while its mate runs on the low part of the tread close to the rim, and in a short time we will have a worn flange wheel on one end of the axle and a worn tread on the opposite.

(3) The practice, followed in some shops of only taking one cut in boring out wheels should be discontinued, as it is not practical to get a good wheel fit without taking a finishing cut. The New York Central R. R., I believe, sends a practical man to look after the turning up of axles, fitting and mating of wheels, at contract shops where they have cars under construction. It seems to the writer that this is a very good practice, and one that all railways could profit by.

(4) Where practical, wheels made by the same manufacturer should be mated on the same axle, as a very slight variation in the turning up of the chill will make quite a difference in the shrinkage number of the wheel, and by mating two different makes of wheels we are quite likely to get a hard and soft wheel on the same axle.

The design of a pattern is one of the essential factors in the manufacture of the cast wheel, other than the thickness of flange, shape of hub and tread. The designing of the pattern should be left to the discretion of the manufacturer. A large percentage of wheels that fail in the brackets can be ascribed to a poorly designed pattern; too light a bracket will crack because they cool more [illegible]ddly than the plate of the wheel, which would cause a s[illegible] on them; too heavy a bracket will throw the strain [illegible] the plates, causing the plates to crack.

For the benefit of those who are not familiar [illegible] the drop test used in testing wheels, Fig. 1 gives an i[illegible]ra-tion of the Barr drop; Fig. 2 the M. C. B. drop.

It will be noted that the hammer of the Barr [illegible]rop strikes the single plate of the wheel (A) Fig. 1. Th[illegible]m-mer of the M. C. B. drop strikes the hub of the wh[illegible] (A) on Fig. 2. A wheel rarely fails in service in th[illegible]ub, double plates, or at the intersection of the plates, [illegible]et-ters (A), (B) and (C) on Fig. 2. If a crack does o[illegible] at these points it does not necessarily cause the wheel [illegible]e-come dangerous. If a crack occurs in the single [illegible]e, we then have a dangerous wheel and it will not ru[illegible]g before giving way entirely. Wheels tested under t[illegible] M. C. B. drop are placed flange downward on an anvil [illegible]k, having three supports for the flange of the wheel to rest upon. The hammer strikes the central part or hub [illegible]od the whole of the wheel resists the concussion. The wheel tested under the Barr drop is placed flange downward [illegible] a flat surface anvil block, and received the concussion at [illegible]e point only

The C., B. & Q. R.R. specifications require wheels t[illegible]ed

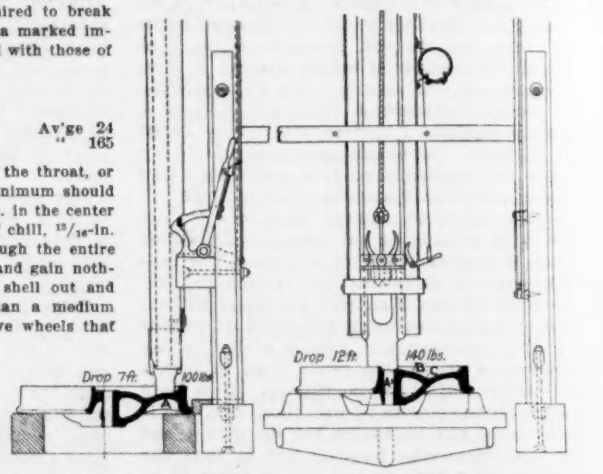


Fig. 1.—Drop Designed by J. N. Barr, Mech. Supt., B. & O. R. R.

Fig. 2.—Standard Drop Recommended by Master Car Builders' Association.

DROPS FOR TESTING CAR WHEELS.

under the Barr drop to stand 50 blows without breaking out a piece. The Pennsylvania R. R. specifications, I believe, require wheels to stand 12 blows under the M. C. B. drop without breaking out a piece. It would seem fair to assume that the Barr drop would find the weak or dangerous part of the wheel more readily than the M. C. B. drop.

The treatment and handling of the hot wheel has nearly as much to do with the strength as does the material used. Cold iron will produce seams in the tread, internal strains, because the molten iron sets in the mold as fast as it is poured. Hot iron with slow and uneven pouring, produces a sweat in the throat, uneven chill and internal strains; delay in getting the hot wheel in the pit after being shaken out of the mold, will also produce strains in the wheel by uneven contraction. To overcome these undesirable results it is necessary to have hot iron and fast pouring. The maximum limit of time in pouring a 33-in. wheel should not exceed twelve seconds. Wheels must be gotten into the annealing pits expeditiously after being shaken out of the mold. The annealing pits should also be covered properly.

Table No. 2 gives the analysis of a number of wheels tested under the Barr drop and in the thermal test.

	Results of wheels in two tests.							
	In thermal test.				In Barr drop test.			
	Failed.		Stood.		Failed under 50 blows.		Stood 50 blows & over.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Total carbon ..	3.91	3.63	3.90	3.38	3.37	3.42	3.93	3.49
Graphitic car. .	3.02	2.92	2.98	2.71	3.19	2.90	3.02	2.90
Combined car...	.89	.71	.92	.67	.68	.52	.91	.59
Sulphur	.090	.042	.10	.080	.080	.020	.070	.05
Manganese	.60	.49	.58	.48	.62	.40	.72	.47
Silicon	.82	.50	.91	.50	.97	.67	1.10	.68
Phosphorus	.48	.39	.52	.26	.58	.30	.53	.28

The failing of some of the wheels under these tests cannot be ascribed to the composition.

A NEW MOVING STAIRWAY.

There appears little doubt that the "moving stairway" or endless belt incline as a means of transferring passengers from one floor to another of a building is likely to become an important feature in the design of railway stations, stores, public buildings, office buildings and similar structures. We believe the greatest credit

*Abstract of a paper presented before the Western Railway Club, Oct. 10.

†Wheel Inspector, C., B. & Q. R. R., Aurora, Ill.

for the development of this machine is due to Mr. Jesse W. Reno, of New York City, who has for nearly a dozen years devoted a large part of his time to the perfection and commercial introduction of this apparatus. The Reno machine was illustrated and described in our issue of Aug. 25, 1892, and a considerable number of them are now in service. At the Paris Exposition moving stairways by four different manufacturers are in operation. Besides Mr. Reno's machine, two French exhibitors have machines closely resembling his, and a peculiar and interesting machine, which we expect to describe in an early issue, is shown by the Otis Elevator Co.

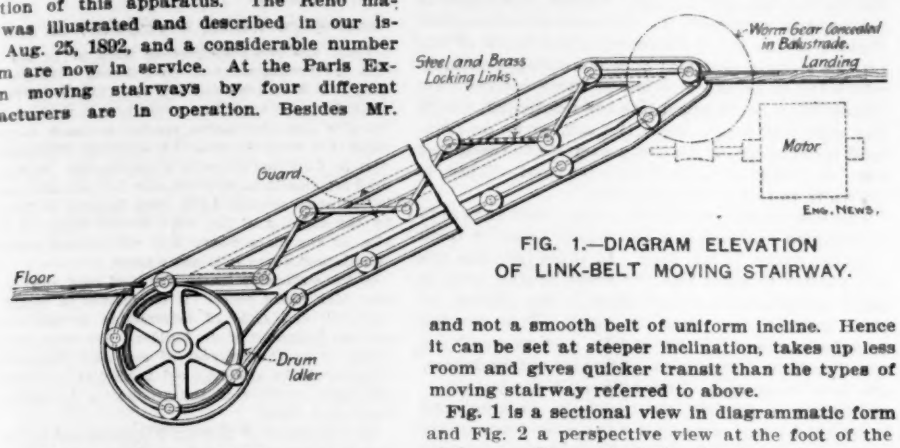


FIG. 1.—DIAGRAM ELEVATION OF LINK-BELT MOVING STAIRWAY.

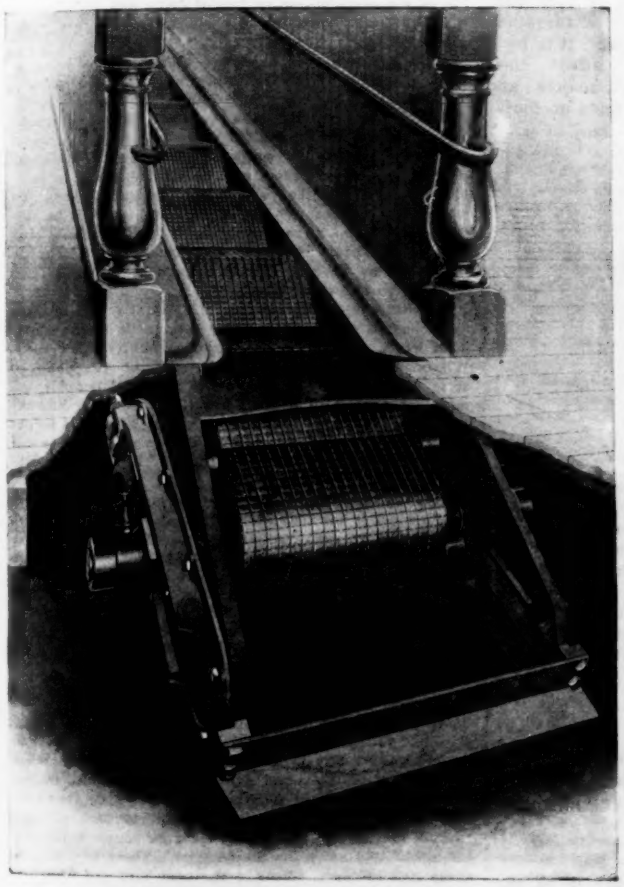


FIG. 2.—FOOT OF LINK-BELT STAIRWAY, SHOWING ADJUSTING APPARATUS.

The machine illustrated in the present article is of still more recent development, and while it accomplishes the same object as the others is of radically different construction. In the Reno and the two French machines referred to, the stairway is really an endless belt, moving at slow speed, and while rubber projections on its upper surface help to give a secure foothold, it has to be set at considerably flatter inclination than an ordinary stairway. This not only takes up valuable room but makes the time of transit from floor to floor longer than is desirable. In the New York elevated railway stations, for example, it is said that many passengers walk up the stairs rather than take the moving stairway because they can go up more quickly.

In the apparatus herewith illustrated, the stairway is really a stairway or flight of steps and not a smooth belt of uniform incline. Hence it can be set at steeper inclination, takes up less room and gives quicker transit than the types of moving stairway referred to above.

Fig. 1 is a sectional view in diagrammatic form and Fig. 2 a perspective view at the foot of the stairway with part of the flooring cut away to show the machinery. The endless belt is made up of sections of steel links and these are deflected into a zig-zag course to form treads and risers on the ascending side by cross bars carried by small wheels. These wheels move between guides, and the arrangement is such that they pass alternately into the upper and lower passageway on the ascending side, as seen in Fig. 1.

The alternate shafts are guided into the upper and lower tracks by means of a fixed frog:—the shafts that take the upper track are longer than those in the lower track and this, together with slight differences in the construction of the rollers makes it possible to guide these shafts with absolute certainty each into its proper course without the necessity for any moving switches or parts whatever.

At the head of the stairway the belt is passed around a sprocket roller of small diameter, seen in Fig. 3. Power is transmitted to this roller to drive the belt by a gear wheel on the same shaft operated by a worm, driven by an electric motor. The arrangement at the foot is shown by Figs. 2 and 4, and it will be seen that wear of the links can be compensated for by an adjusting mechanism at the foot of the stairway.

The stairway is 3 ft. in width from rail to rail, and the moving belt constituting the steps is 21 ins. wide, so the passengers ascend in single file. It is practicable to operate it at a speed of 90 ft. per minute, at which speed it has a capacity of 3,000 passengers per hour and requires about 5 HP. of electric current. It is set on an incline of 26°.

The machine is the invention of Mr. Jas. M. Dodge, M. Am. Soc. M. E., President of the Link Belt Engineering Co., of Philadelphia, and is being put on the market by the Stair Lift Co. of Nicetown, Philadelphia.

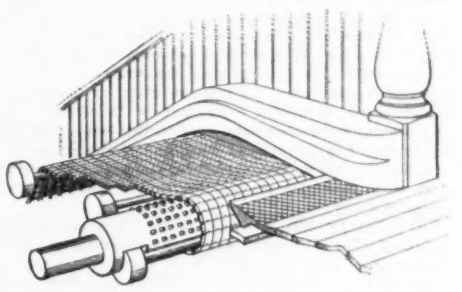


Fig. 3.—Sprocket-Driving Roller at Head of Link-Belt Stairway.

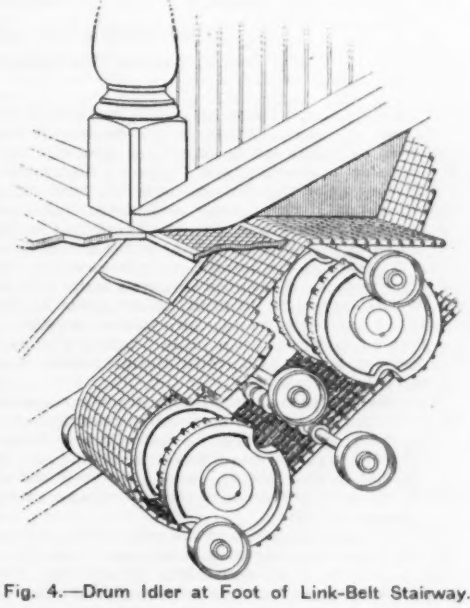


Fig. 4.—Drum Idler at Foot of Link-Belt Stairway.

SMOKELESS COMBUSTION IN LOCOMOTIVE FIREBOXES.*

By A. Bement.†

The problem of preventing smoke from locomotives having been before this club for investigation, the following, treating of some of the details of the combustion process, is offered with the hope that it may be of interest.

*Abstract of a paper presented before the Western Railway Club, Oct. 10.

†Consulting Engineer, 218 La Salle St., Chicago.

Carbon may leave the furnace, in three principal forms: First, that of $C + O_2 = C O_2$; second, $C + O = C O$, which are invisible gases, or third in a free state furnishing the coloring matter for the gases when known as smoke. European experiments would indicate that under extreme conditions the free carbon escaping as soot or lamp black in the smoke would not exceed 1.5% of the total in the fuel. In the foregoing, carbon which may escape in such combinations as $C H_4$ or $C_2 H_4$, or in any other combinations which may exist in the coal, or may be formed in the furnace is neglected, as not having a bearing on the question under consideration.

A smokeless condition would imply that all of the carbon not escaping in the form of hyrdocarbons, would be oxidized to $C O_2$ or $C O_1$ or both; and a smokeless condition with complete combustion as far as carbon is concerned, would require that all of the hydrocarbons be broken up and that all of the carbon be oxidized to $C O_2$. There are two factors generally recognized as being necessary for smokeless combustion: (1) high temperature; (2) liberal air supply. To these I would add a third, and arrange them in a different order of importance: (1) temperature; (2) what may be termed mixture; (3) air supply. As illustrating the meaning of the term "mixture," it may be assumed that 1 lb. of coal and 11 or 12 lbs. of air are placed in a hot chamber, and that the gases are thoroughly mixed together. The result will be that all of the carbon will be in the form of $C O_2$, the hydrogen in that of $H_2 O$, and sulphur as $S O_2$; and if less than the theoretical amount of air be employed the result, as far as carbon is concerned, will be that there will be C O present and a reduced amount of $C O_2$.

The locomotive firebox with its comparatively cold walls tends toward a lower furnace temperature, as compared with a brick lined furnace. The very high rate of combustion on the other hand, however, tends toward a higher temperature, because of the rapid generation of heat as compared to the cooling capacity of the walls. This may be illustrated by saying that what may be termed the temperature head is higher. With the same gas analysis but different rates of combustion, the more intense heat would show a higher temperature of the gases above the fire. Temperature would be lowered from two causes. The most serious in the locomotive is from large amounts of fuel being supplied at a single coaling and from increased air supply.

In the matter of mixture, if every atom of carbon were attacked by one or two atoms of oxygen, the problem would be solved as far as smoke is concerned. But the tendency is for air to enter in masses, and for the hydro-

carbon gases to pass from the fuel in like manner, and while a volume of gas may be in contact with a volume of air, their molecules are separated and there is no combination. It is probable that the force and violence of the combustion process in itself, promotes mixture in a slight measure. Also, the molecular activity being greater as the temperature is higher, the effect is in a measure the same; but these influences can have but small effect as their range and scope is small. The brick arch, so much used in locomotives now, is the instrument of first importance as effecting mixture. Second to it is the steam jet; each promoting a stirring up and mixing together of hydrocarbon gases and air. The arch is an obstacle in the path of the gases, changing their direction and promoting a more thorough intermingling, with the effect of causing the contact of carbon and oxygen, and when this is secured the combination is instantaneous. The direct effect of the arch on temperature is very slight. It is, of course, true that at times heat is stored up and given up at other times, but it is so small in amount as to be of no material consequence. Its indirect effect on temperature, though small, is favorable, because by its action in stirring the gases together more combustible is oxidized with a corresponding increase of heat and temperature. The arch being of brick, and, therefore, at a high temperature, is of more value for the purpose than if made of water cooled surfaces.

The steam jet, like the arch, is an instrument promoting mixture, by stirring up and beating together the gases. Mechanically, it is very effective if properly applied, but is not equal to the brick arch. It has the effect of reducing temperature, owing to the high heat capacity of steam. It should have charged against it the steam taken from the boiler, and the heat carried away. When the use of jets is accompanied by the reduction of smoke, it is because carbon has been brought in contact with oxygen, and for no other reason. While it is difficult to arrive at any definite conclusions as to what the possible heat loss may be when the jet is used, it is probable that in many cases combustion is promoted to an extent that makes up the loss incident to its use, leaving the reduced amount of smoke as a gain.

Large air supply is accompanied, necessarily, by low furnace temperature, and low temperature is favorable for the production of smoke. Within certain limits, however, very large air supply may be effective in promoting mixture, and show a favorable result. This is a characteristic of stationary boiler fires that are under long brick arches which maintain a high furnace temperature, and allow the fire to be drowned with air. In this way the carbon may all be oxidized because each atom has several times as much oxygen as can be used, ready to combine when opportunity offers. If the same air supply exists with the fire directly exposed to the boiler, smoke cannot be prevented. I have found cases where it was necessary to cut down air supply to reduce smoke. Excessive air supply, however, is a condition which does not usually cause smoke on locomotives.

When the admission of air over the fire is accompanied by a reduction of smoke, it is caused by the oxidation of carbon rather than by dilution. And cold air admitted over the fire is in no wise different in effect from cold air admitted through the fire bars, except that the air through the grate is liable to be better distributed, affording a superior mixture.

While the foregoing refers to the action of the furnace and the combustion process in connection therewith, it takes no account of the management or operation. This I find to be the most important factor, and that too much is expected of some particular device or method, and too little attention given to the quality of the work done by the man.

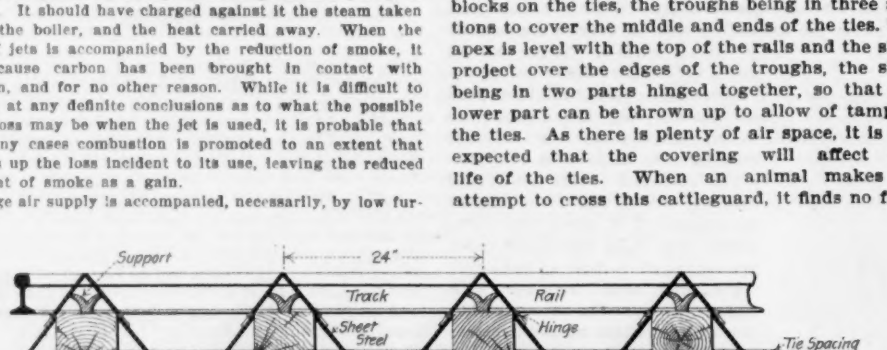
The reduction of smoke from locomotives will require considerable improvement in the quality of work performed by the fireman. The brick arch and the steam jets can only put the finishing touches on his work, which, if not properly done, leaves more for the arch or jet than they are able to perform. I have yet to find a furnace that will be smokeless, or nearly so, under all kinds and conditions of treatment that it may be subjected to, and do not expect to find such; and it must be said that in much of the prevailing practice, firing is done in a manner that would be required if the production of smoke were the important object sought.

COMBINATION PIT AND SURFACE CATTLEGUARD.

While the old style of pit cattleguard is objectionable in many ways, and is an element of danger to traffic, it has proved more effectual in turning stock than some of the surface cattleguards designed to supersede it. The specially deterrent feature of the pit cattleguard is the depth of the pit, the sight of which at once discourages animals which try to cross. In view of these conditions a combination cattleguard has been designed, which has sufficient depth below the rail, gives no foothold for animals, and is yet a part of the track and can be readily inspected and repaired. This is shown in the accompanying cut.

The ties are spaced 24 ins. c. to c., and the earth is shoveled out between and below them to form trenches about 14 ins. deep. In these trenches are set wooden troughs like the cross drains used to carry water across the roadbed to the ditches, or steel troughs may also be used. The wooden troughs are 8 × 12 ins. inside, and prevent the trenches from filling, while they also act as drains, the ends being open. Under the rails are put spacing blocks to prevent the ties from shifting, and these blocks are so shaped as to also form struts or braces across the tops of the trenches, preventing the sides from collapsing. Over each tie is set an inverted trough of V-section, supported by blocks on the ties, the troughs being in three sections to cover the middle and ends of the ties. The apex is level with the top of the rails and the sides project over the edges of the troughs, the sides being in two parts hinged together, so that the lower part can be thrown up to allow of tamping the ties. As there is plenty of air space, it is not expected that the covering will affect the life of the ties. When an animal makes an attempt to cross this cattleguard, it finds no foothold, and if it should get its front legs in one of the trenches by persistent attemps to cross, it can easily back out, which it could not do if caught in the deep pit of the ordinary pit cattleguard.

This cattleguard has been in use for some time on the Arkansas Midland R. R., and is also being tried on the Illinois Central R. R. and the Southern Ry. It has been patented by Mr. R. V. Wallace, Roadmaster of the Arkansas Midland R. R., Marvell, Ark.



COMBINATION PIT AND SURFACE CATTLEGUARD.
R. V. Wallace (Roadmaster, Arkansas Midland Ry.), Inventor.

COMMITTEE REPORTS AT THE ST. LOUIS MEETING OF THE ASSOCIATION OF RAILWAY SUPERINTENDENTS OF BRIDGES AND BUILDINGS.

At the annual meeting of the Association of Railway Superintendents of Bridges and Buildings held at St. Louis, Mo., on October 16 to 18, inclusive, three important committee reports were presented on the subjects of Railway Snow Fences; Hand versus Air Riveting for Railway Bridge Field Work; and Concrete for Railway Bridge Substructures, Retaining Walls and Culverts. These three reports, much condensed, are given below. The use of concrete in place of stone masonry and the substitution of portable pneumatic riveting apparatus for hand riveting in railway bridge field work are matters which have come into prominence within the last few years, and although they have been heralded as innovations of surprising merit, few actual comparative figures have been published. It is for this reason that engineers will read with interest the comments of the practical bridge builders who make up the committees appointed by the Association on these two questions. As for the subject of snow fences, it will be recognized as one which is literally of perennial concern to railway engineers throughout the greater portion of the United States.

BEST SNOW FENCE, STATIONARY OR PORTABLE.

There are two principles to work on in the construction and arrangement of snow fences. The one practised most is to keep snow out of a cut; the other is to make the wind that puts snow into a cut, take it out again. A snow fence is any obstruction erected to check the wind and cause it to drop the snow it is carrying, which would otherwise be deposited where it is not wanted. Such fences are used principally at railroad cuts, but are also used around buildings to prevent drifts from forming in front of them by the eddying of the wind around them; at turn-table pits, or any place where they will prevent snow from accumulating where it is not wanted.

Of the stationary fences, the kind used most is the common high board fence. It is modified in height, sizes of material, and style of construction to suit the location and the judgment of the builder. For want of better material or in the interest of economy, fences are sometimes made by standing old track ties or bridge ties on end tight together in the ground, or by building a rail fence with them.

On the prairies of Western Minnesota and in the Dakotas, especially where the land adjoining right of way is unimproved, sod walls are built 4 or 5 ft. high to serve as snow fence. In the location just named snow drifts are almost always frozen hard as fast as they form, and it is common practice there to build walls of cakes of snow and when a drift has formed as high as the wall add another wall to top of drift and continue to do this as the drift rises higher. Our most common forms of portable fences are often placed on top of drifts and staked down until the drift rises above them when they are again placed on top.

Some members have expressed themselves as being in favor of hedges, for the following reasons: "Besides being an efficient fence, when once established they are easily taken care of; will not blow down or get out of repair. They beautify the surroundings and last indefinitely with but small expense for proper maintenance." It is our opinion that where hedges may be planted 100 ft. or more back from a cut, they are a most desirable fence. Or where a low hedge, say five or six feet high, will be sufficient protection, it may be planted on the right of way line which is ordinarily 50 ft. from center of track, but to illustrate how they may grow to be a beautiful nuisance we cite the following example:

The Chicago, Milwaukee & St. Paul Ry. Co. planted cedar hedges years ago at many cuts on its northern division which traverses a fine farming country in Southern Wisconsin. They planted on the right of way line. In spite of the trimmings they have had, and possibly because of neglect to trim by some of the many different men who have cared for them, they have attained a height of 12 to 16 ft. and are so high that snow drifts too far over them and gets on to the track. They add so much to the beauty of the surroundings they will probably be allowed to stand until they make too much trouble. They are so dense it has been necessary to cut them down to the ground 200 ft. each way from highway crossings, so as not to obstruct the view of engineers and people on the highway. Although so dense generally, the foliage of old or overgrown hedges is too sparse near the ground to prevent wind from carrying snow under. This trouble may be obviated by building a low board fence behind them. To maintain hedges properly for many years it requires considerable watchfulness and systematic care to keep them trimmed and well protected from fire.

The most common form of portable fence in use is the board panels 16 ft. long and 8 ft. high made of ordinary 1 × 6 ins. 16-ft. fence boards nailed to three 2-in. × 6-in. 6-ft. and three 2-in. × 6-in. 8-ft. post or legs. These legs are in pairs of one 6-ft. and one 8-ft. piece with their feet spread 5 ft. apart and their tops crossed 5½ ft. above the foot of legs and fastened with one screw bolt through them which serves as a hinge when the panels are closed up to be piled away for the summer. There is a pair of these legs in the middle and one near each end of panel, the foot of the long legs standing toward the cut and those of the shorter legs away from cut when fence is in position. The tops of the long legs overhang the intersection 2 ft. to windward, and have three boards on the under side of this projection to catch the wind as it glances up from the main part of the panel which has seven boards and two bracing cleats on the windward side of the short legs. The spacing of the boards varies from 5 ins. at the bottom to 2 ins. at the top of fence. These panels stand end to end in a fence, but are independent of each other, being fastended only to the ground by nailing the foot of legs to short wooden stakes driven in the ground before it freezes or into frozen snow drifts. When ground is frozen they are fastened with staples to ordinary iron drift bolts used as stakes.

This style of fence has been in use on the Chicago, Milwaukee & St. Paul Ry. farther back than the chairman of this committee knows of, he having first seen it on that company's lines in 1880. It is still their standard portable fence, and cost in 1899 f. o. b. cars $1.59 per panel, com-

posts with stakes and spikes, each panel weighing 327 lbs. when made of green lumber. Many miles of it were built that year on forms faced with iron for clinching the nails. This style of fence is also the standard portable fence on the Union Pacific Ry. and the Colorado & Southern Ry., and is used on the Lehigh Valley R. R.

Mr. J. P. Snow, of the Boston & Maine R. R., says:

On our Eastern Division, which crosses some broad areas of level cultivated land, at slight cuts, we use a portable snow fence made of 1-in. × 6-in. boards nailed to end and middle uprights of the same material, made up in 12-ft. lengths, set up with alternate sections leaning against each other and fastened at top with hooks. This fence is set parallel to the track, perhaps 100 ft. away and affords ample protection. I enclose a letter from Mr. G. K. Thornton, one of our roadmasters, which explains itself. His division is in the mountain region of New Hampshire, and has many snow fences placed at an angle of 45° with the track extending from near the ditch to the location line and on the windward side of the track.

In his letter, Roadmaster Thornton says:

When the prevailing wind is parallel to the track, or nearly so, these diagonal fences will clear the track of snow better than fences parallel with the track.

Mr. A. W. Merrick, of the C. & N. W. Ry., writes:

Our stationary snow fence as used on Minnesota & Dakota Division has 12-ft. cedar posts set 4 ft. in ground and 8 ft. apart, and so placed that the middle post of each panel is on opposite side of the boards from the end ones, rendering it difficult for tramps or other persons to tear boards off. The boards are 1 in. × 10 ins. or 1 in. × 12 ins. and 16 ft. long, running horizontally, spaced 2 ins. apart and fastened with 10d nails, leaving an open space of about 12 ins. next to the ground. Cost of 16 ft. of fence 8 ft. high is:

Six 1 × 12—16 ft. at $14.50 per M..	$1.39
Two 12-ft. cedar posts at 29½ cts..	.59
1½ lbs. 10d nails at $2.40.....	.04
Material	$2.02
Labor.....	.60
Total....	$2.62—16⅜ c. per lin. ft.

Mr. A. A. Page, of the Boston & Maine R. R., builds stationary fences 6 ft. high with spruce boards set close together and upright on three 3-in. × 5-in. 16-ft. girts nailed to posts set 8 ft. centers, the fence costing about 40 cts. per lin. ft. The stationary fence of the Chicago, Milwaukee & St. Paul Ry. is made of 8-ft. boards spaced 1 in. apart and nailed upright to two 2-in. × 6-in. 16-ft. stringers, one lying flat on top of the posts, the other nailed to face of posts near the ground. Posts are 10 ft. long set 3 ft. or more in the ground and 8-ft. centers with a 1-in. × 12-in. 16-ft. baseboard under the upright boards; cost, 23 cts. per lin. ft.

It may be mentioned here that sloping the banks of shallow cuts well back, say to 1 ft. in 10, will, in many cases, remove the necessity for a snow fence. This is being done by some roads, which also miss no opportunity to widen troublesome deep cuts, when material is needed elsewhere for filling purposes, in such a manner as to make more room in them for drifting snow.

It is the practice of railroads in general to maintain a stationary snow fence or fences on their own land wherever they are habitually troubled with snow, and to reinforce this with portable ones when necessary to place more fences farther back from cut and on land not owned by them.

Farmers object to putting any kind of fence on their land for the reason that snow drifts formed by them do not melt off and let the frost out of the ground under them in time for that part to be seeded when the balance of the field is. To save the time, annoyance, and cost of dickering with owners of adjoining property for the privilege of locating fence on their land, our fence should be located on our own land whenever practicable; and where there is no objection to having the fence stand the year around it should be a stationary fence, this being the most durable and economical kind to maintain; and one that will serve for a property line fence at the same time. The fence should be placed 60 to 75 ft. from the track if we own that much land.

The worse the snow drifts, and the nearer the fence is to the track, the higher and tighter it should be. When the stationary fence will not hold all the snow that comes, another line of fence and sometimes three or four lines are put up farther away from cut, at intervals of 100 to 200 ft. apart, one at a time as needed. These extra lines are usually portable for the reason that railroad land seldom extends that far, and the fences if on improved land must be removed during the summer. The panels are folded and laid in piles several feet high on the right of way and protected from prairie fires in the summer by section men burning the grass off the ground for some distance around them.

Whatever kind of fence is used, it should stand across the path of the prevailing wind, and when that wind strikes the cut diagonally, the fence should be broken up into sections placed some distance apart, but parallel and overlapping slightly when seen from the direction of the wind. At the end of the cut the fence should extend beyond and toward the track, to guard the mouth of the cut against quartering winds.

We have known one portion of a road to be repeatedly blocked with snow all through a winter, and not troubled with it again for several winters, while another portion of the same division, only 30 miles away, got all the bad storms the following winter. In such cases, portable fence is picked up and moved to the district where it is needed most. It is best not to build a stationary fence where trouble is first experienced, but put up a temporary one until it is shown that a permanent one will be needed.

High, stationary fences should be built very substantial to stand against hard winds. Posts should be of good material and large diameter. If they are small or of inferior material, two or three years of rotting will weaken them so that the fence will blow over with the first high wind. Cedar and oak posts are best.

This committee's subject is simply "Best Snow Fence," but we assume that that should include anything in the line of structures or suggestions that will help to keep snow off the track, so we call attention to the practice of roads that traverse troublesome snow districts, of locating their station buildings on the opposite side of track from the direction of the prevailing winter winds, so that snow drifts will not form on the main track. Employees of these roads, especially track and bridge men, are instructed to pile no timbers or other material on the windward side of the track so close to it that it will cause snow to drift on to the track.

W. E. Smith; A. McNab; Geo. E. Hawks; A. W. Merrick; W. M. Noon, Committee.

HAND VERSUS AIR-RIVETING; ACTUAL COST COMPARED FOR THE ERECTION OF NEW WORK AND REPAIRING IN THE FIELD.

Since 1890 this company has been steadily replacing all wooden and combination truss bridges with steel, and up to May, 1899, all riveting in field had been done by hand; since May, 1899, we have erected 22 new steel spans of various lengths, aggregating in all 2,455 lin. ft.; besides this we have repaired several old spans taken down, reinforcing, changing floors, raised to safe clearance, etc. In doing this we have used pneumatic tools for riveting, chipping, drilling, reaming, etc. In the erection of the 22 new spans record was kept of the number of rivets driven, viz., 80,065. In the repair work we did not pay as close attention to number driven, but there were a large number.

With pneumatic riveting hammers I find two men and one heater can average daily (10 hrs.) 500 rivets, whereas by hand 250 rivets per day was a good day's work (more often less) for three men and one heater. One day we drove 700 rivets, by using an additional man to take out fitting-up bolts, etc. This was the work of one air hammer only. In inspecting rivets I find the work far superior to hand work—less loose rivets, heads invariably perfect, shank of rivet filling hole, and in every way far superior to hand work done by our men, or by others in the past; also work can be done readily in places where great difficulty has been experienced with hand tools. It seems useless to call attention to the benefit of reamed holes in assembling joints made by pneumatic drills over the "drift pin work," so much in use, where hand riveting prevails; but with the rapidity that air drills run, the expense of reaming rivet holes has been reduced to a minimum. The pneumatic plant in use on this road for bridge work consists as follows: One 12 HP. Fairbanks, Morse & Co. combined gasoline engine and air compressor; two galvanized iron water tanks; one galvanized iron gasoline tank; one boiler iron main reservoir, "large"; one boiler iron auxiliary reservoir, "small." All necessary fittings, etc., mounted on box car; one No. 2 Boyer pneumatic hammer, old style; two New Boyer 000 1 6-16 × 5 ins., pneumatic hand-riveting hammer; two hand steam drills (running them with air), with necessary hand, spring, and air dollies, rivet snaps, forges, drill bits, reamers, and other small tools necessary to this class of work.

The 12-HP. gasoline engine and air compressor furnishes more than enough air to operate all of our tools at the same time. By using the small reservoir at bridge and main reservoir on car, and operating at 90 lbs. pressure, we have had in use at one time three hammers, two drills, two heater forges, and one blacksmith forge, and have been able to get full capacity out of all of them. We use hand riveters only in field work on bridges, as we have not driven over ⅞-in. diameter rivets, and think in such class of work it is more economical than a yoke riveter. In handling larger rivets, repairing or rebuilding work done in yards or shops, a yoke riveter could be worked to good advantage. In filed work there were many difficulties when doing hand work that would cause delays that are now overcome quickly by use of air. In chipping, cutting out, reaming, drilling, etc., work can be done in a fraction of the time that it used to take, and when done you have a good, presentable piece of work; in fact, I consider pneumatic tools are so far ahead and superior to hand work in everything that it is practically unnecessary to dilate their uses. It costs us the same to spur out at bridge site, as we always spurred out when running a hand gang, and by increasing pipe line we can invariably find a good location for the outfit cars with small expense. In putting in staging or falsework for riveters we find the cost is less, and by doing the work faster by air enables slow orders, or delays to movement of trains, to be reduced, and the slowing up or stopping of a train is an item of expense to railway companies.

I have compiled some data showing actual cost of work. We will take up first cost of pneumatic plant. In explanation, would state, I only show increased cost of plant that, in both hand or air, work tools in common; that is, forges, dollies, chisels, snaps, and all such tools, do not appear in this comparison, as one practically offsets the other.

Cost to company for air compressor, reservoirs, machinery, water tanks, hose and fittings, mounted on car	$1,073.00
Three hammers and two steam "air" drills.....	627.00
Total cost of plant	$1,700.00

Cost to maintain since May, 1899:

Repairs to combined engine and air compressor..	$34.00
Repairs to new hammers	6.30
Repairs to old hammer and drills	9.00
Total cost of repairs	$49.30

Proportion of cost of plant chargeable to work per day, on basis of 20 per cent. depreciation per year: Twenty per cent. of 1,700 = per year $340, or per day basis, 313 working days equals year, $1.09. Cost to maintain since May, 1899, $49.30; or per month, 1-17th of $49.30 = $2.90, or per day, 26 days to month, 11 cts.

Cost to operate gasoline engine and compressor per day:

Fifteen gallons gasoline, at 11 1-5 cts	$1.68
Oil, waste, etc.....	.12
	$1.80
Total cost to operate plant per day	$3.00

On basis of running three rivet hammers and forges equals cost for one hammer of	$1.00
Oil for hammer, estimated amount per day	.12
Labor, two men, at $2.40 per day.....	4.80
Labor, one man, at $2.20 per day.....	2.20
Total cost to operate one hammer per day	$8.12

Cost of riveting by hand (as noted on commencement of this detail, there are no charges for tools, as the small tools, forges, etc., not shown in riveting by air, practically offsets tools in riveting by hand):

Labor, two men, at $2.40 per day	$4.80
Labor, two men, at $2.20 per day	4.40
Total cost of hand-rivet gang per day	$9.20

Men with pneumatic riveter will average 500 rivets per day for $8.12, or per hundred, at $1.62 1-5; men with hand power average 250 rivets per day for $9.20, or per hundred, $3.68. The above figures demonstrate that it costs more than double to drive rivets by hand than by using pneumatic tools.

Another point when you have a compressor outfit, when rebuilding old bridges, by putting in a sand blast you are able to eradicate all rust spots that you find in all cases on old iron, which it is practically impossible to do by hand. This leaves iron in perfect condition to receive paint, and you then know that rust spots have not been hidden under a coat of paint.

In closing, will state I think the amount invested in good pneumatic plant is one of the best investments a railroad can make, especially now that steel structures are so much in evidence on all first-class roads.

A. B. Manning, Mo., Kan. & Tex. Ry., Chairman Committee.

At present we have two complete pneumatic plants in the field, each consisting of a 12-HP. gasoline driven compressor and tools. The first plant which we purchased consisted of one compressor, two pneumatic yoke riveters, two pneumatic riveting hammers, and two air drills, one of which was fitted with angle gear for getting into corners not accessible to the drill proper. The first work done with the pneumatic tools was a cover plate job on a 200 ft. through iron span, which required the drilling of about 6,000 holes 15-16-in. diameter through ⅝-in. to ½-in. of metal. Including the cost of setting up the plant for the first time, which was unusually great owing to the inexperience of all hands, the work was done with a saving of about 25% on the cost of doing the work by hand.

We found that the yoke riveters answered the purpose very well in riveting cover plates and other straight work where, when once suspended, they would reach a number of rivets, but they were great time consumers when it was necessary to move frequently. The riveting hammers which were quick acting and short stroke did not give good results—the blow being too light to upset the shank of the rivet to fill the hole, and the concussion of the hammer was very distressing to the operator. We have since secured hammers which have a long, heavy stroke with which we get satisfactory results as to the quality of the work and the effect on the operator is not injurious. We have two plants in use at the present time. The one used by the steel bridge erecting gang consists of the following tools: One 12-HP. gasoline driven air compressor; five long-stroke pneumatic hammers; one pneumatic yoke riveter; one pneumatic clipping hammer; two pneumatic drills, and the usual complement of forges and holding-on appliances used in hand riveting. The yoke riveters hold as well as drive the rivet.

With the long stroke hammers we use the usual suspended dolly-bars, spring-dollies, or lever-dollies, as may be best suited to the condition—the same appliances as would be used were the rivets to be driven by hand—and no more difficulty is experienced in holding the rivets up to the work than were they to be driven by hand. The hammers upset the rivets well into the hole and the heads are very much better than can be made by hand, in fact nearly all heads are absolutely perfect.

Two men and a heater form a riveting gang, and they drive double the number of rivets per day than the gang of three men and a heater where driving by hand.

Where there are a great many rivets of one length to drive, as in lattice girders, water tanks, etc., we use a

portable furnace with an air blast, and one heater supplies two riveting gangs with hot rivets.

The amount of staging required, from which to drive rivets with pneumatic tools, is very much less than is required for hand riveting as it is only necessary to provide seats or standing room for two men, for which oftimes a single plank suffices. In riveting viaduct towers, laterals in spans, etc., where there are only a few rivets to be driven in a place, the saving on erection of staging alone is a very considerable item.

We now have the air compressor set up in one end of a 50-ft. standard tool and material car which, in addition to carrying the compressor, receivers, circulating tanks, and pneumatic tools, serves to transport other tools and rigging from one bridge to another.

We use a Wharton climb-over switch, which is dropped between the rails temporarily and the car is spurred out on a temporary track, as near to the work as is practicable. This saves the expense of handling and setting up the plant on the ground for each bridge, and is much cheaper.

With plenty of storage room for compressed air, so that the pressure will not run down suddenly, we can operate five riveting hammers at once, with a 12-HP. compressor or two drills and two hammers without reducing the pressure to less than 75 lbs.

The drills use a great deal more air than the hammers from the fact that they run uninterruptedly, while the hammers when driving 50 rivets of ⅞-in. diameter per minute are using air only about 5% of the time, which gives the compressor a chance to catch up.

We have a storage capacity of about 80 cu. ft., and I think we could use one or two more riveting hammers by increasing the capacity of our compressed air receivers, as the compressor is frequently cut out by reason of the pressure being at maximum (90 lbs.) and the relief valve open.

With pneumatic tools a great many rivets can be readily driven in places which would be inaccessible to hand tools, from the fact that a rivet can be driven where there is room to insert the hammer which is about 20 ins. long.

The chipping hammer is frequently useful in trimming and capping, and with it all anchor bolt holes in masonry, up to 1-in. diameter, are drilled by simply inserting an + pointed drill and holding it up to the work. Larger holes are drilled with the heavier hammers. There is a saving of about 25 to 40% over the cost of hand work in drilling these holes.

In fitting up the work ready for riveting, a reamer is used in the drills which one man readily handles, and with which all mismatched holes are reamed, and which insures a full bearing for the rivet and does not burr and separate the plates as is the case where drift pins are used. This, while perhaps not reducing the cost very much, improves the character of the work.

We also use the air drills for boring all bolt holes in bridge floor timbers by inserting an auger in place of the drill. This results in a saving over the cost of hand boring of about 50%, which could be further increased, I think, by using the pneumatic boring machines, which run at higher speed and are more convenient to handle.

The cost of fitting up and riveting on new steel bridges (all rivets ⅞-in.) averages to date 35% less than if the work had been done by hand for all work done since we have had the pneumatic tools in use. Work now being done with pneumatic plant costs 40% less than hand work, and we expect to still further increase this percentage as the men become more expert with the tools.

The character of the work is much better than we have been able to do by hand.

In case the work is of too great magnitude for one plant, we install both compressors and combine all of the tools, but usually one plant is sufficient. When not engaged on bridge work we use our second plant in the erection of steel tanks and in timber work, such as cofferdams, grillages, slip sheathing, etc., where there is a great deal of boring to do. In the erection of steel tanks we use the yoke riveter. For the horizontal seams the yoke is hung on rollers which roll on the top edge of the sheet, and for the vertical seams the yoke is suspended by means of light differential pulleys which allow of adjustment of the yoke to the proper height. The chipping hammers are used for calking. The saving in pneumatic overhand work on a 60,000-gallon tank is about 25%.

My experience with pneumatic tools has demonstrated to my entire satisfaction that all work to which they are applicable can be done much cheaper and also much better than by hand.

F. E. Edinger, Southern Pacific Co., Member of Committee.

I have had one 12-HP. and one 22-HP. gasoline compressor at work. The former for nearly two years, the latter for nearly a year on various kinds of work; reinforcing, drilling, riveting, and chipping, both in the field and shop. All air work has been done with a most satisfactory measure of economy over hand work. We have done over five or six times as much drilling with a like number of men as we were able to do with rachets, and in places inaccessible to hand rachets, we do over twice to three times as much riveting with air as we can do by hand, and do the work 50% better. In fact, I cannot say too much in favor of the air machines. They are all that could be desired. I may add, however, that I have substituted the latest patterns of hammers as fast as they have been improved, and wih the best of results.

O. J. Travis, Illinois Central R. R., Member of Committee.

CONCRETE FOR BRIDGE PIERS, ABUTMENTS, AND RAILWAY CULVERTS AND ARCHES.

A list of questions covering the general subject of concrete construction was prepared, and a copy mailed to each member of the Association. In addition, copies were sent to the chief engineer or similar officer of the more important railway lines in North America, which do not have a representative in our Association. Copies were also sent to several cement manufacturers and concrete contractors. The results have been very gratifying. Over 50 replies have been received, the majority of them giving very complete information. These replies come from a wide territory reaching from Canada to Mexico, and from New York to California.

(1) Have you or are you using natural or Portland cement concrete in building foundations, retaining walls, dams, culverts, bridge piers or abutments, or similar structures?

Of 42 replies to this question 39 use concrete masonry in building one or all of the structures named in the question. Three do not use concrete in any form. Of the 39 who use concrete in the construction of various structures, 19 use both natural and Portland cement concrete.

(2) For what class of structures do you use natural cement concrete?

Twenty-nine replies to this question were received. Eleven of the replies were of a negative character, 7 of them stating that they do not use it at all. One states that it is not used on the Pacific coast, because imported Portland cement is cheaper than natural cement in that territory. One used natural cement concrete formerly with poor results, and has abandoned its use. Two used it formerly in footings with poor results and have also abandoned its use. Only four use natural cement concrete where it is exposed to the weather, and this seems to be the growing practice.

(3) What proportions of materials do you use in making natural cement concrete?

The proportions vary from 1 part of cement to 1½ parts of sand to 3½ parts of broken stone; to 1 part of cement to 3 parts of sand, to 5 parts of broken stone.

(4) For what classes of structures do you use Portland cement concrete?

Thirty-three replies to this question were received. The range of uses to which Portland cement concrete is put by those replying, covers almost every class of masonry that the member of a Bridge and Building department is called upon to construct.

Below is given a list of structures named specifically as being built of Portland cement concrete, and the number of those so stating in each instance:

Structure.	No. of those using.
Bridge piers and abutments both foundation and neatwork	17
Foundations of above only	2
Culverts	10
Arches, foundation, and neatwork	6
Arches, foundations only	1
Foundations (all classes)	11
Retaining walls, foundations, and neatwork	8
Retaining walls, foundations only	1
Foundations of buildings	2
Pedestals	3
Copings	2
Facing and repairing old stone masonry	3
Dams	2
Cylinder piers	2
Turn-table centers	2
Facing decaying stone ledges	2

(5) What proportion of materials do you use in making Portland cement concrete? If you use a different proportion for different classes of work, please give that for each class.

The great variation in proportions of materials used for making the same classes of structures would indicate that this feature of concrete construction is a fruitful subject for investigation and experiment. While undoubtedly part of the wide variation is due to the different quality of the materials used, especially that of the sand and broken stone, yet this will only account for a small part. It is our individual opinion that the proper procedure is by careful study and experiment to determine the cement-sand mixture giving the requisite strength for the work in hand, and then to add broken stone in such quantity that the mortar will be slightly in excess of the voids in the stone. Experiments on the compressive and tensile strength of concrete have indicated that the strength depends primarily on the cement and sand mixture provided the mortar is not exceeded by the voids in the stone, and that the greatest strength is obtained when the mortar is only slightly in excess of the voids. On the subject of the proper proportion is dependent not only the economy but also the success of this form of masonry.

(6) Please state the process followed in mixing and placing concrete. If you use a machine for mixing, please state the kind, and say if in your opinion better results are obtained with it than may be obtained by hand mixing.

Many different methods of mixing and placing are followed and condensed extracts from the correspondence showing the different methods follow.

Stone sand and cement are mixed carefully dry, then water is added by sprinkling. Materials are measured in empty cement barrels. Rammed with 1½-in. rammer.

All ingredients are measured. Mortar is m[ixed] first and then stone dumped into it. Deposited in 12-[in.] layers, racked back as to avoid having planes of cle[avage]. During hot weather the top surface of layers is [kept] wet until set.

Broken stone should be spread evenly and [thor]oughly wet. Gravel should be spread over [stone to] an even thickness, and if free from sand should [be wet] Dry sand should be spread evenly over the [gravel to a] smooth surface. Cement should be evenly sp[read over the] sand. The combined layers should not exceed [6 ins. The] materials are then to be turned with shovels [by shov]elers working toward each other from one [turning] without any additional water twice, then a th[ird time wit]h water added as each shovelful is dropped, [and then a] fourth time. Concrete should be dumped in [place. Lay]ers not more than 6 ins. thick, rammed with [rammers not] to exceed 16 sq. ins. on the face nor weighing [more than] 15 lbs.

Four of those replying follow the methods [about] to be described.

Sand and cement mixed dry, then wet. [Stone] after being washed and wet is added to the mortar and turned with shovels until every stone is completely [covered] with mortar. Concrete to be put in place and rammed before it has begun to set.

Sand and stone mixed dry on wood or sheet-iron platform with hoes or shovels. Add water and [turn] again. Spread stone evenly on mortar previously spread, turn with shovels three or four times adding necessary water meanwhile. Deposit in 9-in. layers and ram.

All parts accurately gaged. Cement and sand thoroughly mixed dry and watted. Stone afterwards incorporated and the required amount of water added by sprinkling. Concrete rammed with metal rammers until the water is flushed to the surface.

Mixing principally by hand. Sand and cement dry mixed, then wet, then stone added and mixed with shovels about twice.

Seven use approximately the following process:

Cement and sand dry mixed, wet, and then stone added and thoroughly mixed.

Sand and cement dry mixed, then spread on stone previously wet and then full amount of water added and mass turned until thoroughly mixed, rammed until water flushes to surface.

Sand and cement dry mixed, then added to gravel and mixed.

Sand and cement mixed dry, spread in bed, broken stone placed on top, bed then wet by sprinkling, and rinsed thoroughly until every piece of stone is covered with mortar. Tamped until mortar flushes to surface.

All materials to be actually measured by volume. Either hand mixed or machine mixed with machine of approved kind. For hand mixing sand and cement are dry mixed, then the entire amount of water added, and again mixed. Mortar then spread on the stone previously placed in a thin layer and wet, and mass turned until each particle of stone is surrounded by mortar. Deposited in 6-in. layers and well tamped immediately after being placed.

The variation in thickness of layers in which the concrete is deposited is from 6 ins. to 12 ins., three using 6-in. layers, two 8-in., two 9-in., one 10-in. and two 12-in. The opinions as to the machine and hand mixing of concrete are varied. Four require hand mixing, and six prefer machine mixing by approved concrete mixers.

(7) Do you prefer a dry, moderately wet, or wet mixture? By dry mixture is meant one which requires repeated ramming to bring water to the surface; by wet mixture is meant one which quakes when slightly rammed.

The opinions as to the proper practice to be followed in this respect are quite evenly divided between the advocates of the dry and of the wet mixtures.

(8) Have you experienced any trouble on account of cracks forming between successive layers of concrete especially when one layer has been placed after the one below has started to set? What method have you adopted to obviate this difficulty?

Of the 23 replying to this question, 19 have never had any trouble of the kind indicated and four have had. The four having had trouble of this character qualify their statement as follows:

Not between successive layers of natural or Portland cement concrete of the same kind, but could never join natural and Portland cement concrete.

On ends of wings of abutments seams may sometimes be observed, seldom cracks.

Surface cracks especially where a stoppage occurs close to the top of a wall.

The methods adopted to prevent this difficulty are quite similar and consist generally in having the top surface of the layer of concrete which has set clean, rough, and wet. In addition in one instance the next layer of concrete is made a little wetter, three sprinkle a small amount of pure cement on the wet top surface, another uses a slight excess of mortar in the next layer, and another sprinkles a thin grout over the surface of the layer which has set, and if the location is such that a crack would weaken, iron dowels are placed in the top or stones up to 1 cu. ft. in volume are placed in the top layer with one half of the stone projecting above the surface, or a groove is formed in the top of the layer by setting a plank with its top level with the top of the layer in the concrete before it sets. In any case a stoppage of work within 18 ins. of the top of a wall is prohibited by him.

(9) What, if any, provisions do you make for expansion and contraction due to changes of temperature?

Fourteen out of 25 make no provision whatever for expansion and contraction due to changes of temperature. One makes no provision now, but would if called upon to build a long wall. The general plan followed by the others is to provide planes of weakness or cleavage lines in the wall or other structure from 10 ft. to 75 ft. apart.

(10) Do you face concrete exposed to the weather? Please describe the facing used and method of putting it

on, and say if you have had any trouble with its cracking off.

Fourteen of the 27 replying to this question do, and 13 do not use mortar facing for concrete work exposed to the weather.

There is considerable dissimilarity in the form of facing and and the methods of applying it. Below are given the different proportions of cement and sand used in making facing, one person only reporting in each case:

Cement to 1 sand; 1 cement to 1 sand, 3 ins. or 4 ins. thick; 1 cement to 2 sand; 1 cement to 2 sand, 1 in. thick; cement to 2 sand; 1½ ins. thick; 1 cement to 3 sand, 2 ins. thick; 1 cement to 3 sand, 4 ins. thick; 1 cement to 3 sand, 6 ins. thick and ½-in. of neat cement on the outside; cement to 4 sand, and Portland cement mortar facing 6 ins. thick.

The unanimous reply of those using mortar facing is, that they have experienced no trouble on account of its separating from the body of the concrete. One of those who only uses mortar facing in special cases has had trouble with Portland cement facing separating from natural cement concrete.

METHODS OF APPLYING FACING.—One whose work is rarely exposed to temperature below 20° F. plasters the facing on successfully.

Another plasters board form before putting the concrete on the inside and at other times piles the concrete a short distance from the form and then fills this space with grout.

Another method used is to put the mortar facing against the form and then to throw the concrete against it; after removing the form a thin 1 to 2 mortar is then applied and rubbed down with a cork float, making a neat sand finish.

Another is to plaster the mortar on the inside of the form and ram the concrete against it.

Another places a 6-in. board 4 ins. from the form and fills concrete back of it and then rams it. He then places mortar in the 4-in. space, after which it is again tamped.

Another method used is to have an iron or steel plate 4 ft. to 6 ft. long, of a width equal to that of the course desired. On one edge of this plate two handles are placed and on one side two angles are riveted at right angles to the length of the plate. These angles are of such a size that when the plate is placed with the angles against the form the distance between the plate and form equals the thickness desired. The plate is placed as just described, the concrete is filled back of it, and the mortar between it and the form. Then the plate is removed and both are tamped together before the initial set has taken place.

The following methods are reported for getting a good surface on concrete work without the use of a mortar facing:

Selects fine concrete, and places it around the form and then backs it up with the coarser concrete.

Works fine concrete along the face.

Gets good face by careful selection of concrete. Uses care in placing concrete, selects finer materials and rams it with special wedge-shaped rammer. Gets good smooth face.

Uses care in ramming the concrete close to the mold.

By the use of the shovel or trowel along the face of the form the coarser stone is forced back and the mortar comes to the surface. Gets perfect face in this way."

Selects materials for the face carefully, tamps it well and uses spade along the form. Gets a good face.

The question of the necessity of a mortar face for Portland cement concrete is one of considerable importance. By its use the cost of the work is increased and the speed of the work in narrow walls is frequently delayed.

(11) Please describe the form or mold you use?

The methods of building forms follows a general plan of a framework of timber. Against this frame boards or plank of various thicknesses are nailed, generally horizontally.

(12) Have you had any experience which leads you to think either favorably or unfavorably as to the practice of mixing concrete in freezing weather?

Of the 28 replies to this question 17 are more or less unfavorable to the carrying on of concrete construction during freezing weather, 10 are favorable to it with proper precautions and 1 is unfavorable to the manufacture of natural cement concrete and favorable to the manufacture of Portland cement concrete during this weather.

(13) What has been your observation as to the action of frost on natural or Portland cement concrete after it has set?

Nineteen reply that they have never seen any injurious effects of frost on Portland cement concrete after it has set with these qualifications in two instances, "when of good materials," and "if properly put in." Practically all of those giving the results of their observation as to the effect of frost on natural cement concrete state that they have observed bad results. From the tenor of the replies it would seem that the general feeling is against the use of natural cement concrete where subject to the action of frost.

(14) What difference in cost between concrete and stone masonry do you find?

The almost unanimous report from all sections of the country is that concrete work is cheaper than the same class of stone masonry. The reports in which it is stated that it is of greater or equal cost are as follows:

Mr. Woodman of the Canadian Pacific states that near good quarries where mason labor is not too high and away from cement centers, first-class rubble would be cheaper. Near cement centers and where good broken stone and gravel are easily obtained concrete would be cheaper.

Mr. Fred. Ellers of the C. B. & Q. says that concrete and rubble are of same cost, first-class stone work is double the cost of concrete.

A statement is also made that brick work laid with cement mortar is cheaper than concrete.

Other statements are made that concrete is 50 cents, $1, $2, $2.50, $3, $4 and $5 cheaper than stone masonry; that it is $3 cheaper than bridge stone masonry; that is 30 per cent., 33⅓ per cent., and 50 per cent. cheaper than stone. Also that in abutments concrete is 20 per cent. cheaper than coursed stone masonry with rubble backing, 33⅓ per cent. cheaper than stone masonry in piers, and 50 per cent. cheaper in arches.

A statement is made that it is cheaper than stone masonry when stone is scarce.

Three state simply that it is cheaper or much cheaper than stone masonry.

Mr. W. H. Kennedy of the O. R. & N. Co. states that no stone masonry is used as building stone is too expensive to be economical.

Mr. H. W. Parkhurst of the Illinois Central R. R. states that he has recently built some second-class bridge masonry for the same cost as concrete, but that it is not probable that this can be done except under favorable conditions.

A statement is made that natural cement concrete costs $6 to $6.50 per cubic yard, and Portland cement concrete $8 per cubic yard.

Another statement that concrete costs $7 to $9, sandstone masonry $16, and granite $22 per cubic yard.

It would seem from the foregoing that under ordinary conditions on almost all the railway lines in this country concrete masonry may be built for considerably less than the same class of stone masonry.

(15) Please state any reasons you may have for or against the use of concrete in railway bridge or building work.

The replies to this question are as a rule very favorable to the use of concrete, and they are given in a condensed form below without comment on the part of the committee:

Mr. W. H. Kennedy, chief engineer O. R. & N. Co., states that concrete is perfectly satisfactory and the most economical building material for bridge founuations and culverts to be had on that line.

Mr. A. E. Killam, inspector of buildings and bridges of the Intercolonial railway of Canada, states that he prefers good stone masonry in their new and permanent structures.

Mr. W. G. Curtis, engineer maintenance of way of the Southern Pacific Co. (Pacific System), stated that he was satisfied with concrete construction made in accordance with their rules, for practically all classes of railway bridge and construction work involving the use of masonry.

Mr. W. J. Wilgus, chief engineer of the N. Y. C. & H. R. R. R., states that his experience with concrete has been uniformly satisfactory, and that they have found it especially valuable in the preservation of old masonry on the line of that system, which has failed, due to disintegration of the face stone and in some cases for the reinforcing of foundations. He has found concrete especially valuable in the construction of bridge seats in conjunction with the reconstruction of bridges on the four track line between Buffalo and Albany. This method of construction obviates the use of derricks and other interruptions to traffic incident to the use of stone coping.

Mr. H. W. Parkhurst, engineer B. & B. Illinois Central R. R., states that concrete is preferable to stone masonry on account of its greater cheapness; in fact that the work can be done without the use of derricks and heavy machinery; that complicated structures can be built by the aid of molds and that work can be handled in restricted quarters which would be impossible to carry on with cut stone. It has especial advantage in reinforcing cut stone masonry, either bridge piers, arch culverts, abutment walls, parapets, etc., where a mold can be constructed and a good bond made between the old and the new work.

Mr. L. F. Goodale, chief engineer of the H. & St. J. R. R., gives the advantages of concrete as follows: Convenience; cheapness; the fact that it can be built with unskilled labor and without the use of derricks, and the fact that it can be easily built in almost any shape.

Mr. C. D. Purdon, assistant chief engineer, A. T. & S. F. Ry., is in favor of the use of concrete where placed by experienced men.

Mr. H. D. Cleaveland, master carpenter of the P. B. & L. E. Ry., states that he has never used concrete for abutments as sandstone is so cheap there and he prefers stone to concrete.

Mr. Thos. Rodd, chief engineer Pennsylvania lines west of Pittsburg, gives the following reasons against the use of concrete in exposed work: Appearance. He prefers dimension stone masonry to concrete on account of the more pleasing appearance of the former. Durability. He believes that concrete disintegrates when exposed in this climate unless built with the best brands of imported cement.

Mr. Charles Churchill, engineer maintenance of way of the Norfolk & Western Ry., states that he should not hesitate to use Portland cement concrete if forced to through the lack of suitable stone for ashlar masonry, but that he regards the latter with good stone much to be preferred when procurable at reasonable prices.

Mr. H. F. White, chief engineer B. C. R. & N. Ry., states that in the five years' experience he has had with concrete it has given just as good results as stone masonry.

Mr. G. A. Gould, superintendent B. & B. of the C. R. I. & P. Ry., states that he considers concrete cheaper and better for all ordinary bridge building work than any other kind of masonry.

Mr. W. A. Rogers, engineer Permanent Construction C. M. & St. P. Ry., B & B. Dept., states that during the last three seasons 100,000 cubic yards of concrete have been placed on that line, and that the results have been very satisfactory. He states the following advantages: No derricks required, less interference with traffic, may be built with unskilled labor, wider distribution of concrete materials, less falsework required, permits combination with iron or steel, ease with which structures of irregular and intricate shapes are made, durability, economy, pleasing appearance.

Mr. D. Bontreau, chief engineer of the K. C., Ft. S. & M. R. R., says that an important advantage of concrete is the ability to handle material in places which are difficult of access and in the case of culverts the comparative security against washing out.

Mr. Fred. Ellers, superintendent Bridges and Buildings, C., B. & Q. R. R., states that concrete has been giving them good satisfaction.

Mr. Thomas H. Johnson, chief engineer of the P., C., C. & St. L. Ry., states the use of concrete above ground has been too limited and of too recent date to warrant drawing conclusions therefrom.

Mr. J. Woodman, engineer W. D., Canadian Pacific Ry., says: "It appears to me that there can be no doubt that concrete is, when properly handled, the most suitable and economical material for bridge piers, abutments, railway culverts, and arches or in buildings."

Mr. E. H. McHenry, chief engineer N. P. R. R., gives the following reasons for using concrete: Cheapness; can be built with an experienced foreman and unskilled labor; material is much more easily handled than in stone masonry; results obtained more satisfactory than stone masonry except when built of granite; easily adapted to any form.

Mr. Hunter McDonald, chief engineer of the N., C. & St. L. Ry., says: "I have no good reason for not using concrete, except that I prefer to see the results of its use in a great many places which I have observed, before risking it on structures exposed to great variations in temperature." He also states that he finds brickwork with natural cement very satisfactory and cheaper than concrete.

Mr. H. G. Kelley, chief engineer of the M. & St. L. R. R., states that he has no objection to the use of concrete, that he uses it frequently and is limited in its use only by the question of comparative expense.

In conclusion the committee wishes to state that representatives of railroads having a mileage of over 85,000 miles state that concrete is being used to a greater or less extent on the lines for which they reported.

PUMPING ENGINES FOR THE COOLGARDIE PIPE LINE.

We illustrate herewith one of the six-cylinder triple-expansion pumping engines which are to be furnished by the firm of Henry R. Worthington for the Coolgardie pipe line in West Australia. This pipe line, which has been described and discussed in several previous issues of Engineering News,* is for the purpose of supplying the Coolgardie mining district with water, and is 325 miles long and 30 ins. diameter.

We have been favored by Mr. Chas. G. O'Connor, M. Inst. C. E., Chief Engineer of the Department of Public Works of West Australia, with a copy of the contract for the pumping engines and other machinery, which is a large pamphlet, 43 pages, 8 × 13 ins., with a large folded map. We have abstracted from this contract so much as relates to the general features of the design of the pumping machinery, as follows:

Extracts from the contract with James Simpson & Co., Ltd., of Pimlico, England, with the Director of Public Works of the colony of West Australia, March 9, 1900.

It is agreed that the contractor shall be at liberty to procure from the Hydraulic Engineering Co., styled Henry R. Worthington, of Brooklyn, U. S. A., machinery herein provided for to the extent not exceeding 50% thereof on condition that all similar parts of the said machinery are absolute fac-similes of one another and made to the same templets.

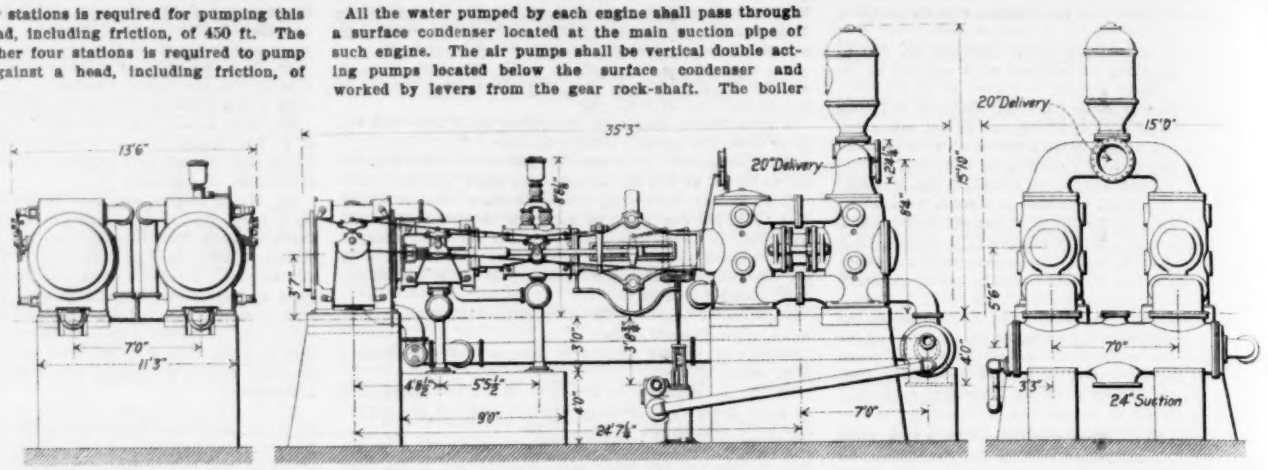
The main is 325 miles long, from Helena reservoir, about 25 miles from Freemantle, to the service reservoir at Coolgardie, divided into 8 sections, with a pumping station at the beginning of each section.

A supply of 5,600,000 Imperial gallons per day may be taken from the Helena reservoir and the machinery of

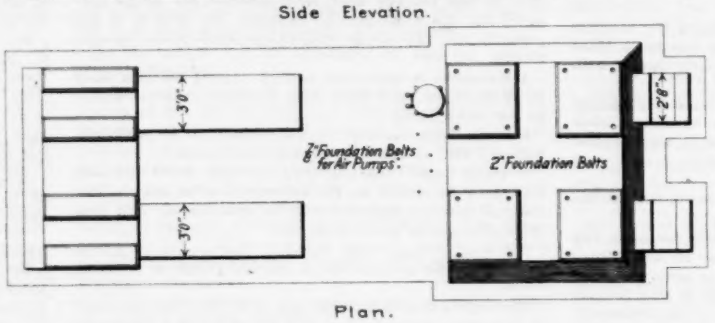
*Feb. 10 and 17, Oct. 13, Nov. 17 and Dec. 29, 1898.

each of the first four stations is required for pumping this supply against a head, including friction, of 450 ft. The machinery of the other four stations is required to pump the same supply against a head, including friction, of 235 ft.

All the water pumped by each engine shall pass through a surface condenser located at the main suction pipe of such engine. The air pumps shall be vertical double acting pumps located below the surface condenser and worked by levers from the gear rock-shaft. The boiler



HORIZONTAL, TRIPLE-EXPANSION HIGH-DUTY PUMPING ENGINE FOR THE COOLGARDIE PIPE LINE, WEST AUSTRALIA.



Chas. G. O'Connor, M. Inst. C. E., Perth, West Australia, Chief Engineer.

Jas. Simpson & Co., Pimlico, England, and Henry R. Worthington, New York, Contractors.

At each of the first four stations three groups of machinery are to be supplied, each of which shall be capable of pumping one-half the supply, and any two groups shall be capable of pumping the whole supply against a head of 450 ft. At each of the second four stations there are to be two groups, each capable of pumping the full supply against a head of 225 ft. Each group at each station is also to be capable in an emergency of pumping one-half the supply against a head of 450 ft.

A group consists of one boiler, one duplex steam engine with six cylinders, and one duplex double-action pump with externally and centrally packed plungers, with all the accessories essential to the working thereof.

The engines are to be furnished with surface condensers and attached air pumps. The boilers are to be of the Babcock & Wilcox water-tube type. The engines and boilers respectively shall be precisely similar to one another throughout, so that any part of one shall be interchangeable with the corresponding part of another. The pumps at the first four stations shall also be precisely similar to one another and the same condition shall apply to the pumps at the second four stations.

Each of the 20 engines shall have two high-pressure cylinders, each at least 16 ins. in diameter, two intermediate cylinders at least 25 ins. in diameter and two low-pressure cylinders at least 46 ins. in diameter, all to be of uniform stroke of at least 36 ins. The plungers at each of the first four stations to be at least 42½ ins. in diameter, and at the second four stations to be at least 20¼ ins. in diameter. The normal speed of the pistons shall be 150 ft. or 25 revolutions or double strokes per minute.

All steam cylinders to be jacketed, including ends, with boiler steam, the circulation to be made in a closed circuit. Low pressure cylinders to be fitted with dash relief valves for regulating cushion and the length of stroke. The cylinder heads to be removed from each of the cylinders so that any piston and any cylinder barrel may be inspected and the piston springs removed independently from each cylinder without the necessity of disturbing the other cylinders.

Main steam and exhaust valves to be of the Corliss type with gear readily accessible and convenient for lubrication. They shall be so proportioned as to reduce the port clearance to the lowest possible limit. They shall be driven by wrist plates operated by the opposite set of reciprocating parts of the engine to that to which they strictly belong. The steam valves at the upper side of each cylinder shall be combined admission and cut-off valves; all bearings shall be adjustable. The valve spindles shall be so connected with the valves that they shall be free to lie close to their seats by their own weight and also by the action of the steam.

The total expansion is to be capable of being adjusted by hand while the engine is at work, the points of cut-off being shown by indices. The valves to be arranged so that each can be set and adjusted independently or dismantled, removed and replaced without interfering with the others or requiring the removal of lagging.

The Worthington high duty compensating attachment is to be used to transfer the excess of effort of the steam at the beginning to the end of the stroke.

feed pumps fitted to each engine to take water from a hot well.

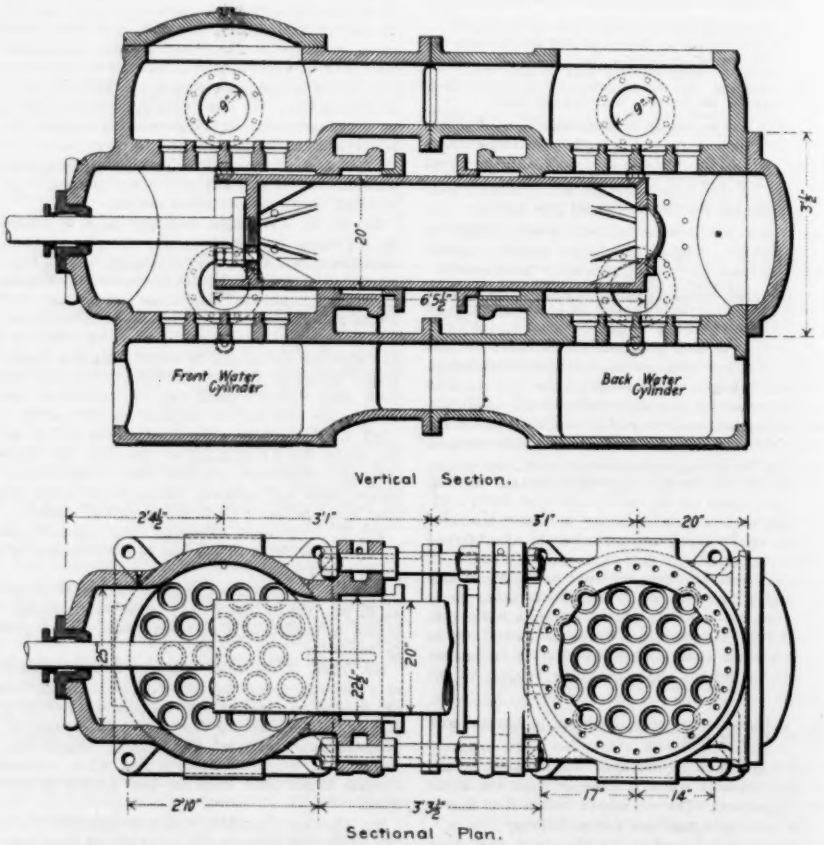
Boilers, 170 lbs. working pressure per sq. in.; not less than 1 sq. ft. heating surface for every 2½ lbs. of steam used per hour. Grates for burning Collie coal having an evaporation of 6½ lbs. of water per lb. of coal. The ratio of air space to dead space in grate to be about 1 to 1½.

Superheaters must be provided capable of adding 120 degrees superheat to the steam. Economizers with cast-iron pipes and separators to be provided. A grease extractor is to be provided at each station.

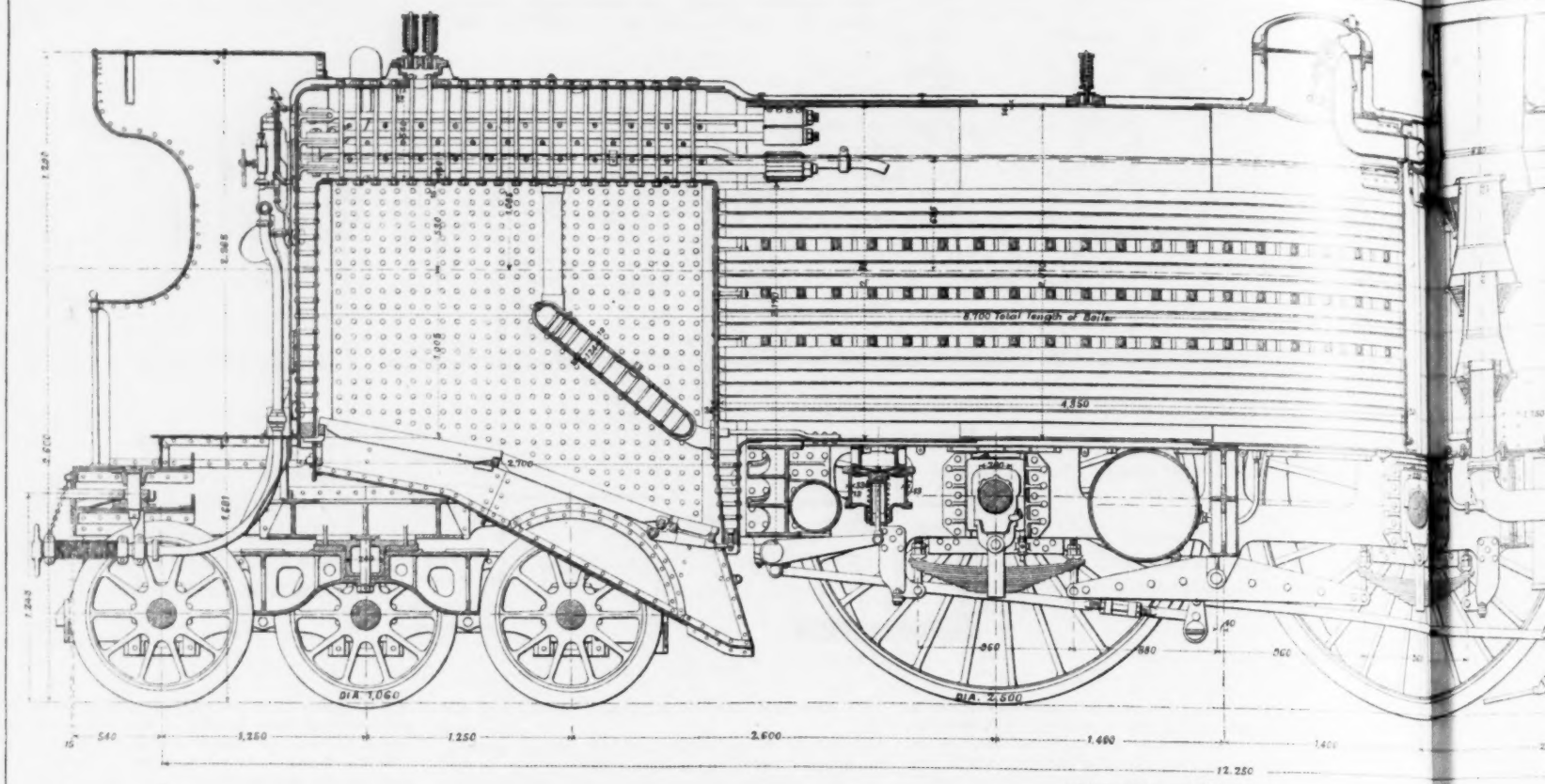
Duty test: 135,000,000 ft.-lbs. of effective work per million British thermal units supplied to the engine and which would not be returned to the boiler in the ordinary course of working. Combined duty of pumping engines and boilers to be 135,000,000 ft.-lbs. effective work for every 100 lbs. of coal, such coal to be equal to a fair sample of Collie coal having a calorific value of 10,000 B. T. U. per lb.

The test for capacity will be made with steam at 150 lbs. per sq. in., the machinery to be capable of performing the work specified with this pressure and with such ratio of expansion as will give a terminal effective pressure not exceeding 6½ lbs. per sq. in.

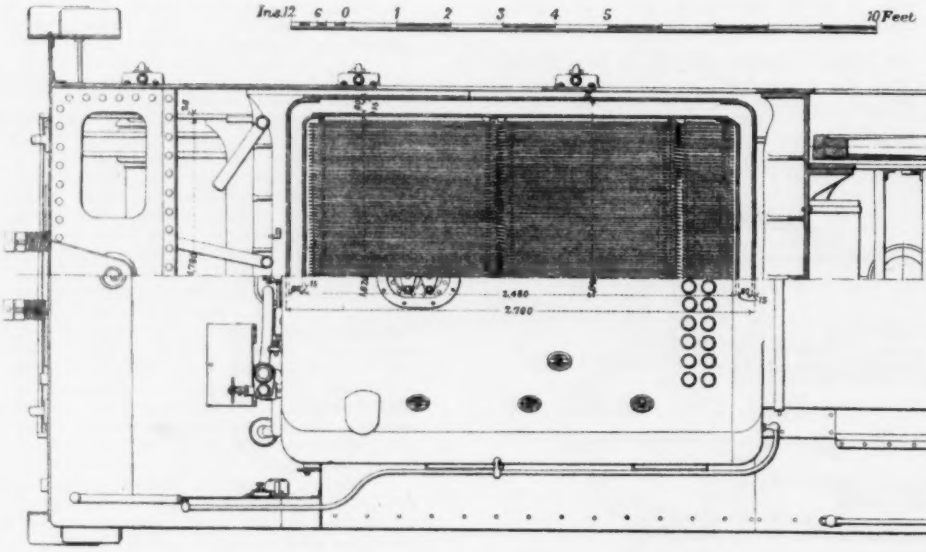
Time of Delivery: The machinery to be delivered in complete working order in 24 months from the date of the contract at the first four stations; in 26 months at stations 5 and 6; and in 27 months at stations 7 and 8.



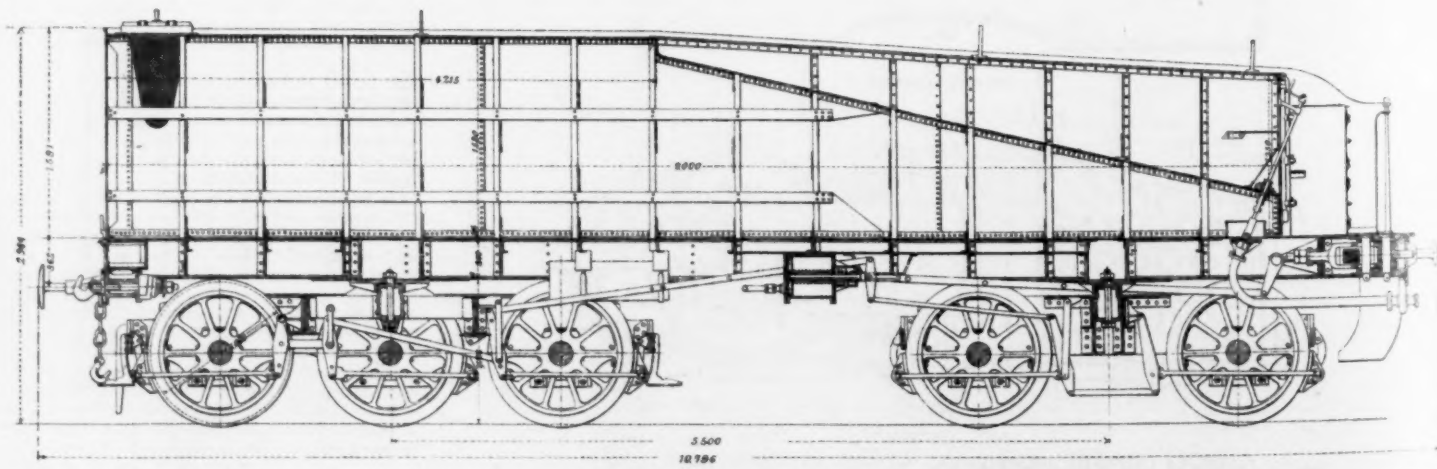
SECTIONS OF WATER END OF COOLGARDIE PUMPING ENGINE.



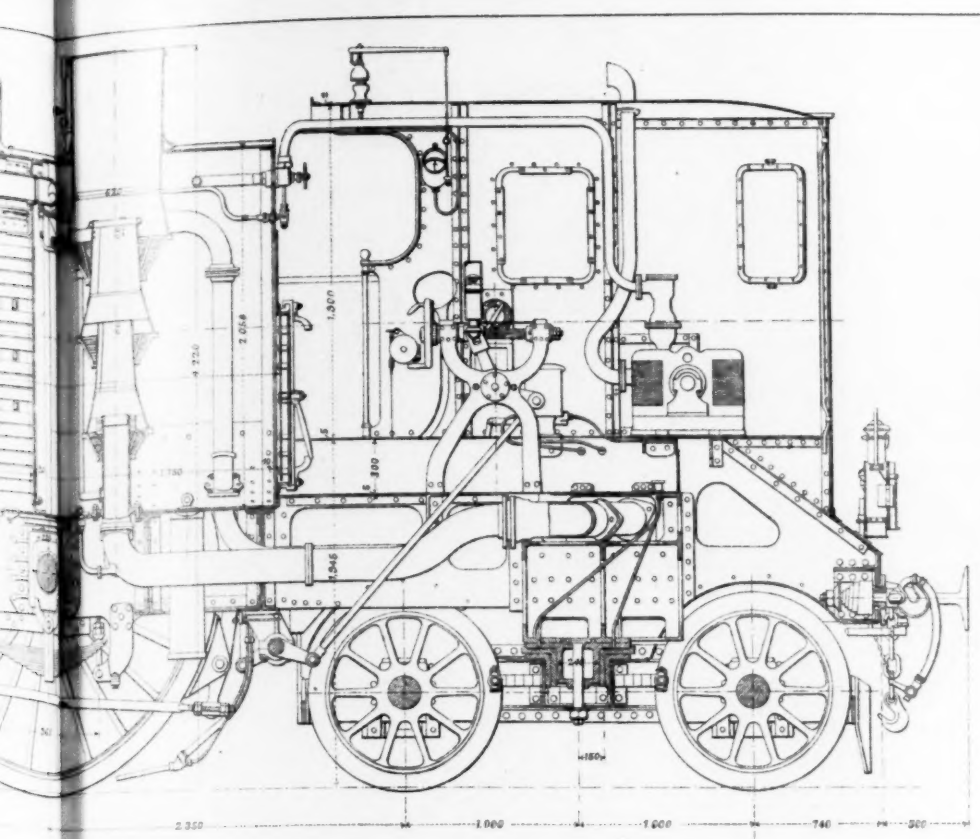
SECTIONAL ELEVATION.

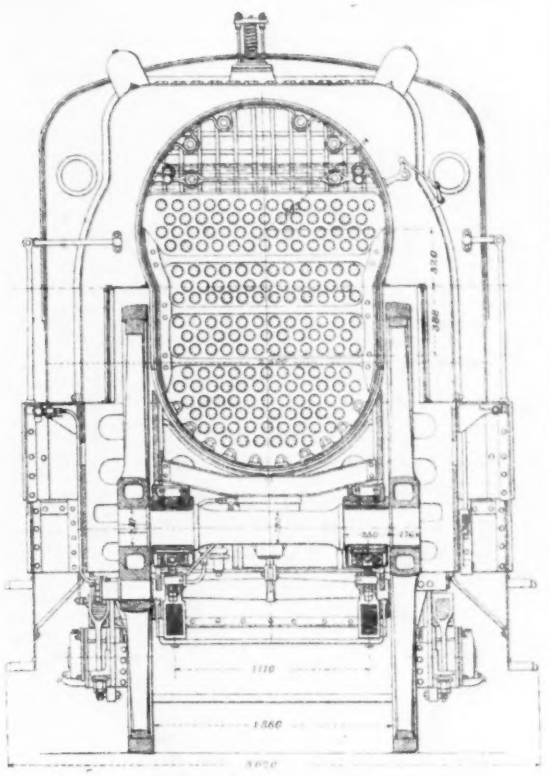


SECTIONAL PLAN.

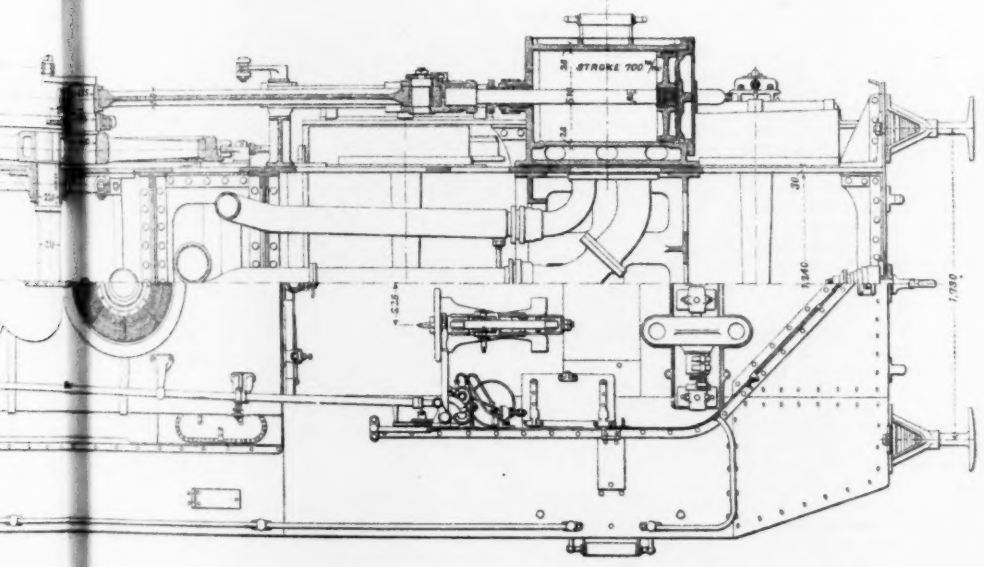


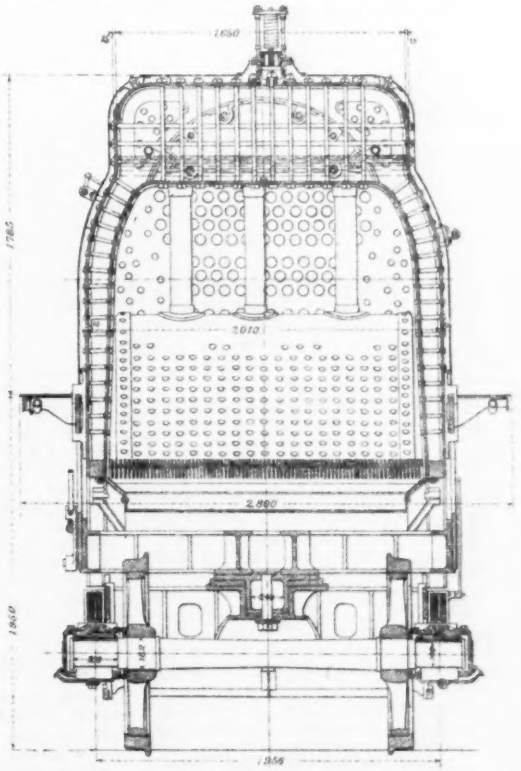
SIDE ELEVATION AND CROSS SECTIONS OF TENDER.



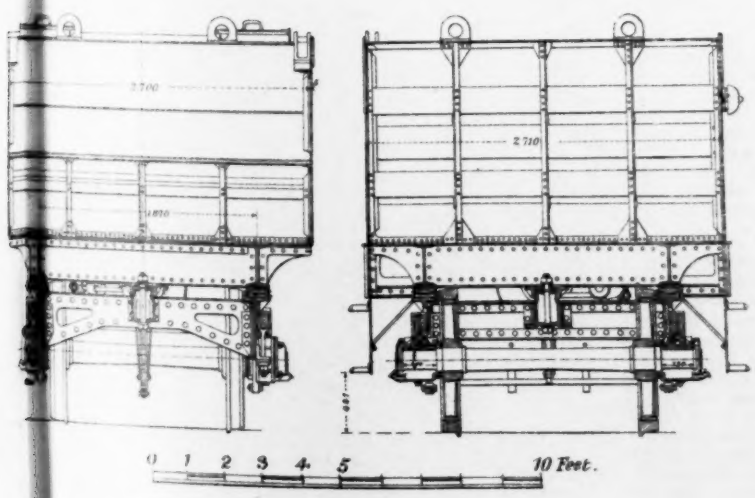


CROSS SECTION THROUGH BARREL OF BOILER.





CROSS SECTION THROUGH FIRE-BOX.



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